ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Vol. 9 JULY–SEPTEMBER, [illegible] No. [illegible]

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

Founded, managed, edited and published by

EDMUND H. FULLING

at

The New York Botanical Garden

Economic Botany is published quarterly. Subscription price per annual volume everywhere is $[illegible]; price per single copy is $[illegible]. Subscriptions and correspondence may be sent to the office of publication, Box [illegible], Lancaster, Pa., or to Economic Botany, The New York Botanical Garden, New York 58, N. Y., and checks should be made payable to Economic Botany. Typescripts should be double-spaced. Photographs will be considered only if of high photographic quality.

Published Quarterly, one volume per year, January, April, July and October.
Box [illegible], Lancaster, Pa.

Entered as second-class matter March [illegible], at the post office at Lancaster, Pa., under the act of March 3, 1879.

ECONOMIC BOTANY

Devoted to Applied Botany and Plant Utilization

VOL. 9 JULY–SEPTEMBER, 1955 NO. 3

Loofah—*The Sponge Gourd*

The sponge gourd has a long history of cultivation in most tropical countries of the world. Its principal uses are based on the closed fiber network that forms a resilient mesh in the walls and core of the fruit, similar in structure to that of a sponge. As oil and water filters in marine engines it was an important item in wartime supplies of the navy. Its early service as food and medicine is almost negligible in contrast to the many more recently found civilian uses ranging from bath sponges to shock absorbers and soundproof linings.

W. M. PORTERFIELD, JR.[1]

The subject of this account is a sprawling vine bearing the scientific name, *Luffa cylindrica* Roem., and producing a cucumber-like fruit which owes its current rating of importance to an internal fibrous skeleton in the form of a spongy network. Varieties and forms of this species in times past have been cultivated as garden plants and occur naturalized in most tropical countries. Where the fruit has long been used for food, it is often associated with another species, *L. acutangula* Roxb. For example, in India both *L. acutangula* and the edible or sweet "variety" of *L. cylindrica* are extensively cultivated in the province of Bengal and eaten as food. As a source of vegetable sponges, however, the former of these two species is relatively unimportant, and since it is this aspect of the latter plant that interests us most and was the principal reason for its promotion to the forefront of wartime strategic materials, the following pages will be devoted primarily to *L. cylindrica*.

Nomenclature

The term "sponge gourd", connoting its structure and use, is a common name by which the fruit of *L. cylindrica* is widely known. However, the one most often appearing in trade literature is "loofah". The Chinese, by use of their characters which phonetically read "Szu (Ssu) Kua", call it "snake gourd". "Po Kua" is also listed as a Chinese name. Other English names are "dishcloth gourd", "towel gourd" and "vegetable sponge". Variations of "loofah", such as "loofa", "loufa", "loopha" or "lufa", have appeared from time to time. The Japanese name has been given as "Naga ito-uri", but it is also referred to as "Hechima" (Hetchima). To illustrate the high esteem in which this gourd has been held in Japan, the poet Masaoka Shiki (10), with his dying breath, was said to have addressed the spirit of "Hechima". Up to 1937 at least, the anniversary of his death was observed as Hechima-ki or "loofah day".

In the Philippine Islands it is called "Patolang bilog" or "Patóla". Other Tagalog names of local use are "Patulang-uak", "Salag-salag" and "Tabubok" (13). In Malaysia the name in Malay is "Blustru" (Bloostroo); in Sundanese it is "Lopang" and "Oyong". In Siam it is called "Būap kom"; in Sumatra, "Kĕtola" which is sanskritic, and "Timput". The Spanish name used in Latin American countries is "El Estropajo". The Mexican Indians, who have long cultivated it, call it "Sonayote" or "Cuazacamecate" (16). These

[1] 1247 30th St. N.W., Washington 7, D. C.

Photos by courtesy of The New York Botanical Garden.

names have their origin in the Aztec tongue. For example, "Sonayote" in the Aztec was "Tzon-ayotli" which is a combination of "Tzontli" (hairy in the sense of hair- or fiber-producing) and "Ayotli" (gourd). In Hungary, where it has been introduced and was first successfully cultivated by John Szabo (1), the name is "Hálós tök".

The botanical name of the sponge gourd most widely accepted is *Luffa cylindrica* Roem., although in the past the plant has been described under other names, and authors have used these synonyms in their writings. Many of these synonyms are contained in the following list, but it is in no way complete: *Momordica cylindrica* L., *M. operculata* Blanco, *Luffa aegyptiaca* Mill. (sometimes appearing as *L. egyptica*), *L. arabus* Vesl., *L. Fabiana* L., *L. foetida* Hort. (not Cav.), *L. japonica* L., *L. mexicana* (?), *L. petola* Ser., *L. striata* Schrad., and *L. Veitchii* Naud.

Origin, Discovery, Distribution

Cultivation of the sponge gourd is of such ancient origin that it is impossible to determine whether the original home was in Africa or Asia. An inhabitant of the tropics and of the warm countries, it is claimed by many to have sprung from the eastern hemisphere, though those who know its historic background in Mexico might be inclined to contest this assertion. Some authorities think that its original home was in tropical Asia and that it still can be found wild there, one even specifying that as many as three or four varieties grow wild in India. Bretschneider, however, who included the sponge gourd in his list of Chinese plants first introduced by him into cultivation in Europe and North America, never saw it in the wild state. On the other hand, because the name "luffa" is of Arabic origin, and because the sponge characteristic of loofah was described in writings concerning Egypt over three centuries ago, it is quite easy to reason that this plant might have come originally from northern Africa.

The evidence well establishes the fact that, irrespective of origin, cultivation of the loofah plant has persisted in China, Japan, Malaysia, India and the Middle East since early times, and that it was grown primarily for food, medicine and ornament. In Chinese literature it is stated that the sponge gourd was not known before the T'ang dynasty (600 A.D.). This may be taken to mean that it had not been introduced before that time, or that its use had not become known until then. In this connection it is interesting to note that early Portuguese explorers, not Chinese, in Asia were the first to discover the practical value of the fibrous tissue contained in the gourd. One may read about the "loufah" sponge in the writings of Vesling in Egypt back in 1638. But even before that, Hernandez, physician to Philipp II of Spain (1536–1598), in his monumental natural history of Mexico described the "Tzonayotli" or "Estropajo" among the cucurbits of "New Spain" (16).

The modern era in the history of its cultivation began in Japan where, between 1890 and 1895, the sponge gourd was first grown commercially. The initial justification for the culture of sponge gourds on a commercial scale is based on the particular fitness of their skeletal network for many practical uses, and the special emphasis on their increased production is due to their successful employment as filters in marine steam engines and also in diesel engines. This special use had made them important to the United States Navy. Since the time Japan started growing and exporting sponge gourds, almost the entire commercial supply of the United States has come from Japan. After Pearl Harbor this supply was suddenly cut off. The same catastrophe which stopped their

importation enormously increased the need for them, constituting at the same time the greatest single stimulus to their wider distribution and cultivation.

Official recognition of the great importance of the sponge gourds was given on April 8, 1942, when the War Production Board, in order to conserve the country's stockpile, issued an order forbidding delivery, sale or use of loofah sponges except on the highest priority (19). Not only was the worth of sponge gourds thus officially established, but under a program of encouragement, the U. S. Government by this one official act gave considerable impetus to its spread to fresh regions where new sources of supply might eventually be established. Attempts to grow loofahs on a commercial scale in the States of California, Alabama and Florida were not successful, but the tropical countries to the south (Mexico, Haiti, Cuba, Dominican Republic, El Salvador, Guatemala) in a year's time were cultivating and exporting "el estropajo" to the United States.

The United Kingdom similarly inaugurated a series of tests in various colonial countries, and after a year sample luffa sponges were received by the Colonial Products Advisory Bureau from Jamaica, Cyprus, Gambia, Nigeria, Nyasaland, Southern Rhodesia, Sierra Leone, Tanganyika, British Guiana, Uganda, St. Kitts, British Honduras, Gold Coast and Antigua. Although some good sponges came from the test plots of Antigua, British Honduras and Nyasaland, the samples from the colonial countries in most instances were not up to the standard Japanese "loofahs".

With the end of the war and with the recession of the shipbuilding program, the demand for sponge gourds fell off, and since again ample quantities of sponges began coming from Japan, and at a price which the colonial products could not equal, the incentive for their worldwide cultivation to establish independent sources of supply no longer existed.

FIG. 1. Cultivated loofah in New Jersey.

Uses

Before World II 60% of the imported loofah sponges were employed as filters, which indicated their usefulness to the U. S. Navy, and 40% of them were applied to civilian uses. However, it can be said that, besides filters for the Navy and for steam engines in general, the military uses of sponge gourds range all the way from surgical operations to cleaning windshields of jeeps. Much industrial equipment requires the cleaning that only the loofah sponge can give. In more detail the special use of loofah

sponges in steam vessels consists in the fact that water condensed after expansion in the engine is passed through several layers of closely packed loofah sponges to rid it of oil and dirt before it enters the boiler to be used a second time. Substitutes were tried when the supply of vegetable sponges was suddenly cut off, but all of them proved unsuitable. Cellulose sponges, turkish toweling, coke and Spanish moss were tried, but for different reasons these would not suffice. It is interesting to note that loofah sponges have a similar use in internal combustion engines, such as diesels, except that the filtering function here is to remove carbon and metal dust from the oil.

Sponge gourds are also made into bath sponges—more acceptable in Europe since the slightly scouring effect is a little harsh for American complexions—and in Hungary are part of the equipment of the masseurs in therapeutic baths. Other products are pot holders, table mats for hot plates, door mats, bathroom rugs, insoles, sandals and gloves. To make gloves or insoles, it is necessary first with a sharp knife to slit down one side of the sponge, remove the central core, and open it out flat; after which it is passed between heated rollers. From the sheet form thus produced patterns for gloves can be cut. Also in this form combined with crude rubber excellent rubber soles for sport shoes can be made. Combined with plaster and varnished over it makes soundproof and heat-proof wall boarding.

Besides being useful for cleaning motor cars, loofahs are also good for cleaning glassware and kitchen utensils. When combined with other materials, toys, matting and hats may be made. Because of their scouring property, they can be used very effectively to rub down painted surfaces. Because of their peculiar structure, loofahs make fair shock absorbers. This useful aspect, as well as their capacity for absorbing sound, has been exploited in steel helmets and armored vehicles of the U. S. Army. Loofahs make good packing material and stuffing for pillows, matresses and saddles; also shoulder pads and stiffening material. Baskets are made of them and, in Mexico, bottle covers. Because they provide good insulation against heat, they are used in Japan in the manufacture of sun helmets.

The use of sponge gourds for food is limited to the cultivated "sweet" variety and is restricted to young fruits before the internal fibers have started to harden and before the purging substance which develops as the fruits ripen has had time to appear (6). At this stage they may be eaten sliced like cucumbers, or in soups like okra, or cooked like squash. By comparison, however, they are inferior to the common variety of squash. In India they are eaten boiled or in curry. In Japan the young fruits are sliced and dried and are thus prepared for future use. Young leaves are eaten in Malaysia but are rather insipid. Annamites eat the male flowers and flower buds.

If an incision is made in the stem of a young vine before time to harvest the fruits about one inch above the ground, a clear liquid may be extracted which the Japanese say has medical value in respiratory complaints. It also makes good toilet water, and preparations from the juice have been marketed as Eau de Hechima, Creme de Hechima, and Dentifrice de Hechima. It is a custom in Japan to cut the stems of the loofah plant about five feet from the ground after all the fruits have been harvested. The top of each stem is then bent round so the cut ends lead into a receptacle. Into this the sap flows and is collected. As much as half a liter of sap may be obtained from one plant. This is used by the Japanese women for rubbing on the face, hands and body, and is re-

garded as an excellent substance for softening the skin and for giving it a fine fresh appearance.

Wilson (24) stated that the fiber is esteemed as a medicine in China. Furthermore, the ripe fruit if burned and pulverized is said in old Chinese medical literature to have healing properties. According to Stuart, it is "carminative, pectoral, cooling to the blood, antiseptic, anthelmintic, emmenagogue, quickening to the circulation, galactagogue, and is also used in the treatment of hemorrhage from bowels or bladder, hemorrhoids, menorrhagia, joundice, hernia, and scarlet fever. Mixed with vermilion it is used to dry up smallpox pustules. Fresh fruit is considered to be cooling and beneficial to the intestines, warming to the stomach, and tonic to the genital organs". Leaves are used in skin diseases and orchitis, the vine and root in decayed teeth, ozena and parasitic affections. Juice from the leaves is given in amenorrhea.

The pure seed oil extracted in Brazil is suggested as a possible substitute for olive oil. While the oil cake, because of bitterness and probable toxicity, cannot be used for feeding animals, it could serve as a useful manure on account of its wealth of protein and phosphates.

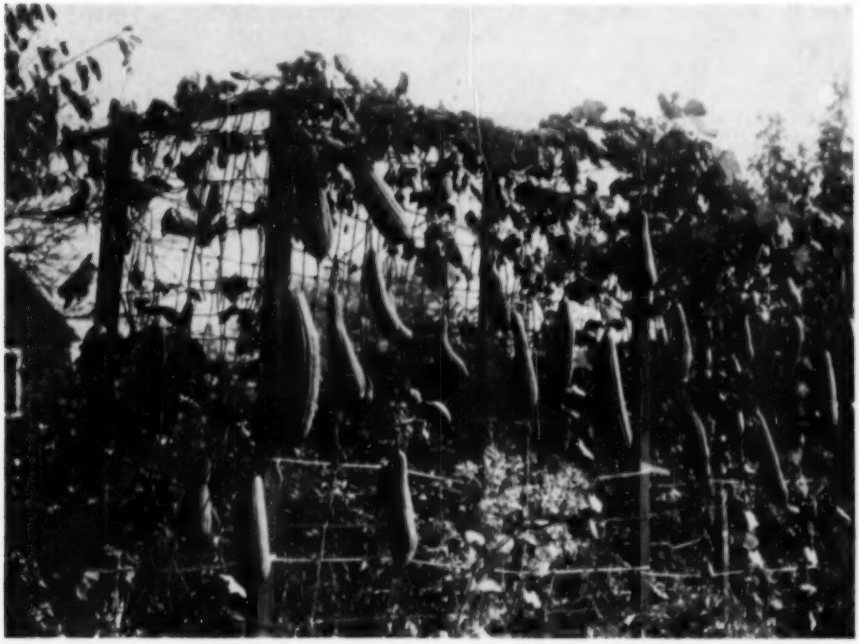

FIG. 2. Cultivated loofahs in New Jersey.

Physical Characteristics of the Plant

Luffa cylindrica Roem. is one of about eight species of the genus *Luffa*, all of which are annual tendril-climbing herbs of the family Cucurbitaceae.

The stem grows long and branches, and is capable of climbing over tall trees. The leaves are roundish in out-

line, mostly five-lobed, coarsely toothed, scabrous above and below. The flowers are large—sometimes as much as four inches in diameter—yellow, attractive, with five-petalled corolla. Stamens and pistils are in separate flowers, and staminate flowers usually two to three inches across, clustered in the axils of the leaves. In the pistillate flowers the ovary is cylindrical or club-shaped, pubescent, destitute of distinct ridges, and ripening into a slender cylindrical curved fruit, one to nearly five feet in length (6½ feet have been reported). The fruit is green, smooth, without longitudinal ridges such as identify the fruit of *L. acutangula* Roxb. The seeds are black, rarely whitish, are about the size of watermelon seeds, and are narrow winged.

The fruit is made up of a smooth outer wall forming a thin rind, marked by ten longitudinal lines, dark green and somewhat degressed. Through the wall and throughout the pulpy interior is a closed network of fibers which harden and become woody as the fruit ripens. The seeds are contained in the core of the network whose principal value as far as the plant is concerned seems to be, according to one interpretation, that it provides for a gradual liberation of seeds over a long period of time as the fruit hangs on the vine. When ripe the rind can be readily removed, and because the soft internal material has mostly disappeared, only the compact fibrous network remains, which is the sponge of commerce.

One variety of *Luffa cylindrica* in India is considered edible in the young stages and is intensively cultivated in Bengal for food, but another is bitter and grows wild. The bitter form is toxic, but except for its bitterness and slightly darker color, it is scarcely distinguishable from the edible variety. This calls to mind the species growing in Mexico, *L. purgans* Mart. (*L. operculata* Cogn.), which has been cultivated by Mexican Indians in Guerrero and Michoacan as a household remedy because of its purgative properties (16). Investigation has shown that, in this species at least, the bitter principle is contained in the rind. This species is valued also because it produces a sponge with fine and soft fibers, although it is small.

Bose (8) undertook to investigate the cause of poisoning by the bitter variety of *L. cylindrica* in India. Two glucosides were isolated from the fruit. One of these was found to act as a severe emetic, the other as a brisk cathartic, causing much irritation and giving rise to dysenteric symptoms. The edible varieties are believed to owe their freedom from toxic substances to cultivation.

The fruit contains saponin and mucus besides the glucosides. This accounts for the soapy feel of the pulp and juice. A food analysis of the fruit yields the usual components in the following proportions:

	Original material	Water-free material
Water	94.66	....
Protein	0.51	9.57
Fat	0.19	3.72
Carbohydrate ...	3.31	61.99
Crude fiber	0.46	8.58
Ash	0.41	7.65
Undetermined ...	0.45	8.49

The results of a mineral analysis conducted in the Philippine Islands are set forth in the following tabulation:

	Fresh samples		Water-free samples		Ash	
	A	B	A	B	A	B
Water ...	95.99	95.36	....	....	....	....
Ash	0.60	0.63	14.89	13.50	....	....
P_2O_5	0.12	0.11	2.96	2.39	19.90	17.71
CaO	0.03	0.04	0.64	0.81	4.32	6.01
Fe_2O_3 ...	0.004	0.003	0.09	0.06	0.62	0.41

The calcium-phosphorus ratio for sample A is 1 : 4.6 and for B it is 1 : 2.9.

By feeding tests young loofah fruits have been found to be low in vitamin B. The vitamin C content is only fair. The

results of tests (25) to show the amount of vitamin C in mg./g. of pulp is tabulated as follows:

mg./g.	Method
0.039	Harris
0.092	Iodine
0.110	After H_2S

There is more vitamin C present than is indicated by the values obtained with Harris' method. It was thought that the vitamin might be present in a reduced form, a conclusion which was borne out by treatment of the fruit extract with hydrogen sulfide. The caloric value was 103 calories/lb. (about 23 calories/100 g.).

The seeds are about 49% testa and 51% kernel, and give a green oil with a high acid value. This oil is of the semi-drying type and remains liquid at ordinary temperatures. The seeds also contain colocynthin which is the basis of their medicinal use, quite independent of the oil (6). Extraction of the oil by solvents gives a pale green oil; extracted by pressure the oil is yellowish. If it can be drawn so that it is pure, it can be used for food or cooking, the bitter purgative properties remaining in the residual oilcake. In the pure state the oil is colorless, odorless and tasteless. The acid components of the seed oil are grouped as follows:

Saturated acids:		
Palmitic acid	56.45%	Constituting 16.93% of the total mixed fatty acids.
Stearic acid	43.85%	
Unsaturated acids:		
Oleic acid	48.73%	Constituting 83.07% of the total mixed fatty acids.
Linoleic acid	51.27%	

Aside from the fatty oil, the kernel contains 6.13% water. In the water-free material the oil content is 45.72%, nitrogen 6.55%, pentosan 2.31%, reducing sugar 3.11%, crude fiber 2.89%, glucosides none, P_2O_5 1.83%, and ash 4.75% (of which 38.54% is P_2O_5). The testa of the seed contains 11.3% water, 0.45% nitrogen, 0.056% P_2O_5, and 0.96% ash (of which 5.38% is P_2O_5) (22).

Propagation and Cultivation

Propagation is by seed. The seeds resemble those of watermelon and are ranged in three lengthwise groups along a central core through the length of the fruit. In the skeletal stage each seed is contained in a pocket. After ripening, the tip of the fruit drops off, and as the pulp dries the seeds gradually loosen. One by one the seeds are shaken free of their pockets by wind and rain, and drop to the ground through the hole at the lower end of the gourd. The average number of seeds produced by a single gourd is not known, but the quantity has been observed to vary directly with the length of the fruit. Information concerning the relation of fruit size to seed size and its possible influence on size of fruit in the next generation is not yet available.

The methods used in cultivating loofah plants depend on the region of operations. Although native to the tropics and warm-temperature climates, good results have been obtained in temperate regions as far north as Connecticut, but a somewhat modified technique must be employed. Because the summers are shorter and frosts come early, growing loofahs in the northern latitudes involves the use of indoor or hot-bed planting in early spring. In New Haven, by starting plants indoors, fruits with good fibers were obtained before frost (19). In Rahway, New Jersey (11), seeds were planted in April in a hot bed, fertilized with chicken manure, and the seedlings were set out after May 15. Some of the fruits obtained measured as much as 26 inches in length. Moreover, seeds produced by these gourds were used to plant the next year's crop.

According to an old custom in China, seeds are planted in the second moon, and the flowers bloom in the sixth or seventh moon. In Japan seeds are sown

in outdoor beds in March or April. As soon as the first two leaves have developed, the young plants are set out in ridges three to four feet apart with the same distances between the plants in the rows. The explanation of the apparent paradox that the best loofah fruits, which normally would be expected from naturalized tropical plants, are obtained from temperate Japan is thought to be connected possibly not only with the volcanic nature of the soil but also with proper attention to fruit pruning, careful processing and strict observation of soil needs.

According to experience in Central America, the soil should be moderately rich; a slight clay loam gives best results, but manuring may be necessary if the soil is not rich enough. Moreover, it should be well drained but located near enough to water to ensure a cool moist atmosphere and watering when necessary. The plant is not truly drought-resistant, though dry season planting is more successful than wet season planting. In Nyasaland (9) an entire crop suffered badly during a drought. On the other hand, rain damages the flowers and creates conditions favorable to invasion by insects and fungal spores. The dampness of tropical Java (Tijpemeuh) was thought to be the reason why out of an estimated yield of 80,000 gourds from a plot, only 3,000 were actually harvested, and these were of inferior length and color. Finally, like all cucurbits, the loofah plant is tender and is, therefore, sensitive to frost. Because of this fact care must be taken not to plant seed or set out seedlings before the danger of frost has passed.

At Tengeru in Tanganyika (9) Japanese loofahs planted in February on a bench terrace at an altitude of 4,000 feet, where the soil was a volcanic loamy type with good drainage and rainfall averaging 45 inches, showed 100% germination, and after two months had completely covered the ground and started to set fruit. Under Tengeru conditions the plant appeared to be drought-resistant. Stones were used to support the fruits off the ground and to reduce damage caused by rot of the fruits. There was no incidence of pests or diseases on cultivated plants or on a local strain which was growing wild. The largest fruit was 15 inches long and had a girth of 12 inches. The results showed that the loofah plant was easy to establish from seed and would grow well under ideal conditions, and furthermore might also be useful as a cover crop. The experiment was not pursued, since Japanese loofah sponges had again become available.

The best gourds are obtained by training the vines over trellises, thus assuring maximum exposure to the sun and preventing the fruits from coming into contact with the ground with resultant discoloration and distortion of shape. In selecting the site for a trellis, protection from wind is an important consideration. Since some fruits weigh as much as five pounds—and there are as many as 25 gourds on a vine—the frame and supports of the trellis must be strong. Heavy posts seven feet tall, or two posts placed like an inverted "V", are planted every 12 feet, with slender supports at three-foot intervals between them. Horizontal members are then fastened to these, spaced three, five and seven feet from the ground. Chicken wire has been used to support the lower part of the plants, or the young plants were tied to the uprights. Without support the vines will climb over the ground and up over the neighboring trees.

In Central America it has been the practice to plant two seeds at the base of each vertical post, to be thinned to one plant after germination. The vines should be tied to the horizontals of the trellis with vegetable fiber like raffia. Some advise at this point that as the plants grow the side branches should be pruned to encourage growth of the main

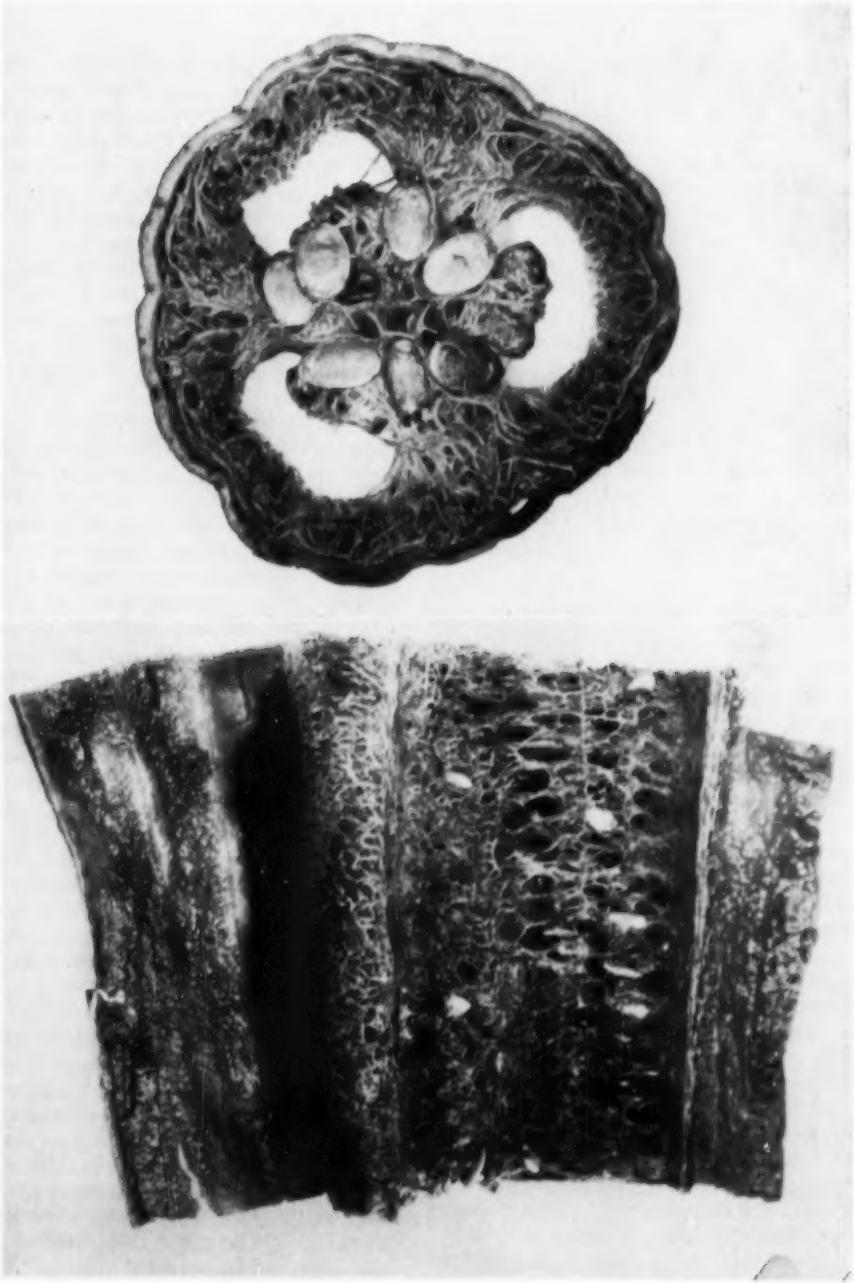

FIG. 3. Longitudinal section (lower) and cross section (upper) through loofah gourd.

stem. It is the custom also to remove all male flowers until the vines have covered all the horizontals. Some growers remove early female flowers, as these are said to produce smaller fruits. Newly formed gourds should be examined and pruned during the first week if they are deformed, pear-shaped or coarse. It is good to limit the number of fruits per vine because by doing so fruits of good length can be produced. The optimum production per vine in the opinion of many growers should be limited to 20 fruits. Harvesting normally commences four or five months after planting.

Maturity of the fruit is indicated by yellowing of the base and apex. Ripe fruits are lighter in weight than unripe ones. When cut, a length of stem should be left on the fruit for convenience in handling.

Diseases and Insects

Although no extensive study of diseases or pests harmful to the loofah plant has been made, experience has shown that it is subject to attack by both insects and disease. In an experimental plot at New Haven, Connecticut, in the summer of 1942, though north of its natural range, no difficulty with attacking insects or diseases was encountered (19). Neither cucumber beetles, squash bugs nor borers were found on the plants. This in itself was not considered conclusive inasmuch as frequent spraying had been employed and it had been a favorable growing season. Also, no cases of mosaic disease were noted, and the leaf-spot disease harmful to lagenaria gourds did not appear. The record elsewhere, however, has been less satisfactory. Insects were thought to be one cause of the poor results obtained from attempted large-scale commercial cultivation in India.

Cultivation and growth of sponge gourds came under close observation in the experimental gardens set up by agencies of the United Kingdom in Africa and in Central America after the outbreak of hostilities in the Far East. On Morogoro Farm in Tanganyika (9) fruits set in May were attacked by a fly which proved to be a fruit fly (*Dacus* sp.). In Nyasaland also, 70% of the fruits set during one particularly dry season were destroyed by the fruit fly. Again, insects were a significant factor in a 25% to 30% loss of a 1942 commercial crop in Cuba where the gourds have long been grown for local use.

It seems that when a fly punctures a ripening gourd, the flesh of the fruit eventually becomes a mass of worms and is badly discolored. Besides the fruit fly the plants were also found to be susceptible to eel worm and wire worm. To combat the latter Gammexane powder was used. Against fruit flies Agrocide 3 was used with some success. DDT was not tried. Other attempts to destroy the fly during the feeding period were made by using poison dust of lead arsenate and sugar. Three forms of fungus attack, not identified, were found on plants, and for this, Perenox, a copper dust, gave fair success. In general dusts were more effective than wet spraying.

Yield

As already shown, production of sponge gourds, assuming that the best seed is used, may be seriously affected by a variety of factors—soil, climate, frost, disease and insect attack. The disappointing crop in Java reported by Howes (1931), of which only 3,000 gourds were actually harvested of an estimated yield of 80,000 because of excessive dampness, illustrates this point (8). On the other hand, the partial loss of the 1942 crop in Cuba cited above was the result of insect attack and insufficient rainfall during the growing season, which limited production to only four or five fruits per vine where normally 20 would be expected. In Japan, at one experimental station, 10,773 plants produced 160,000 ripe gourds, or

about 15 per plant. Under experienced management and optimum conditions, however, the yield can be expected to be 20 to 25 per vine, with a total of 24,000 per acre. In New Jersey, 140 ripe sponges were harvested from a 40-foot row of loofah vines (1942), about half of them being as large as the 26-inch specimen sent to the New York Botanical Garden for exhibit.

Processing

Before the fruits are ready for commercial use, they must be processed, i.e., the "skin" removed, the pulp washed out and the seeds extracted. To avoid injury or discoloration of the skeletal fibers, ripening fruits must be handled with care. If left on the vines to ripen and dry, the "skin" can be peeled off quite readily, thus revealing the residual skeletal network which constitutes the sponge. After this the seeds must be removed. This is done either by shaking or by beating the fruit against a stone.

Another method of preparing the "sponge" is to cut off ripe fruits at the stem, then immerse them in tanks of running water for five to ten days until the outer wall disintegrates and can easily be removed. Further retting and washing will remove not only most of the seeds but also a small amount of soapy pulp left clinging to the fibers. The latter process is accelerated in some areas by pounding with a mallet to drive out the remaining substances. When washed, the sponge takes on a clean white color. If allowed to lie around too long unwashed, the sponges discolor and depreciate in value. By exposing the cleaned sponges to the sun and air, preferably by stringing them on wire, they dry and bleach. To attain the whiteness demanded by the trade, further bleaching may be done with hydrogen peroxide. The sponges are then graded and packed for shipment.

Still another method of processing is to hang freshly cut fruits in an airy draughty shed for two or three days, after which the outer skin becomes soft and pliable. The tip of the gourd is cut off at the lower end, leaving a small hole through which water may drip. The internal "sponge" is then extracted from the fleshy rind by running the fingers down the skin of the fruit on one side and splitting it open. They are then thrown into a washing vat of lime water. From there they are transferred to a drying shed. The lime water should be shaken from each sponge before drying. To avoid brittleness, the sponges should be dried slowly.

Trade

For commercial purposes the preferred type of sponge is of a light uniform color, well cleaned and free from seeds. Furthermore, the sponge should have a good shape, a firm strong fibrous network, neither too closely nor too widely meshed. One report states that the sponges which sell the best are those with a length of over 14 inches. Many commercial specimens reach 18 or 20 inches in length. It is obvious that the size and grade of mesh will vary according to the different requirements of the trade; hence the necessity for grading them. When the sponges have been dried, they are sorted by length, those in any one group ranging no more than two inches from the shortest in the group to the longest. According to the Hechima Export Guild in Japan, there are five grades, of which the first four are disposed of to foreign markets (10). These grades are identified as follows:

Grades	Minimum length	Minimum weight
Special	1.5 shaku	14 momme
First	1.4 "	12 "
Second	1.2 "	9 "
Third	1.0 "	7 "
Fourth	1.0 "	1 "

1 shaku = 0.9942 feet.
1 momme = 0.1323 ounces.

The main faults of the sponges received by the Colonial Products Advisory Bureau from the various experimental gardens throughout the British Colonial Empire were their short length, narrow girth, bad color, dirty condition and inferior fiber texture, although there were some very good ones, particularly those from Antigua, British Honduras and Nyasaland (9). In regard to the last named area, it may be stated that in general the color, mesh and softness of the fiber of sponges from Japanese seed were better than those of the sponges from local seed. The superiority of the Japanese sponges results from their being firm in texture yet yielding to ordinary pressure of the hand, and from their having sufficient resiliency to withstand being bent and twisted without causing a breakdown of the fibers after several foldings. The U. S. naval specifications as of 1943 stipulated that sponges must be at least eight inches long and two inches wide, free from pulp, and must contain no more than ten seeds. Under pressure of shortages a length of six inches was being accepted.

For shipping the best method is to pack the sponges as flat as possible, i.e., in press-packed bales. In such bales measuring 3 feet × 2 feet × 18 inches the number of sponges contained, depending on their length, is figured as follows:

Sponge length (inches)	Number of sponges in bale
8–10	5,000
10–12	4,500
12–14	3,500
14–16	2,500
16–18	1,800
18–20	1,200

Until World War II about 60% of the imported sponges were used as filters on naval vessels; 40% were reserved for civilian local needs. After the WPB order of April 1942, all loofah sponges were reserved for military use.

Japan's biggest customer for loofah sponges up to World War II was Germany which bought more sponges than all other countries. Great Britain ranked second. The following tabulation briefly compares the export of loofah sponges in pounds from Japan to Germany, the United Kingdom and the United States for the years 1936, 1937 and 1938:

	1936	1937	1938
Germany	146,302	402,131	299,879
United Kingdom	118,920	146,566	65,743
United States	73,151	95,903	42,330
Total countries	529,121	847,120	703,596

Imports through the port of New York from Brazil in 1937 totaled 1,056,800 sponges; and in 1940, 1,146,000. The total U. S. imports through all ports for the first half of 1941 amounted to 1,851,500 sponges valued at $49,202.00 (2).

Trends in Breeding

The purpose of loofah cultivation is to produce sponge gourds in numbers, size and quality of skeletal network adequate for the special uses to which they are to be applied. The fact that a wide diversity in size, shape, texture of fiber and mesh of network does exist indicates that in order more fully to fill the special needs in dependable quantities there is need of some standardization of type.

In this connection investigation has shown that the width of the two outer zones of fibers which form the bulk of the sponge and help form the wall of the fruit, in addition to the compactness of the net, the diameter of the strands and the length of the fiber cells, varies greatly in different races, and experimental work has demonstrated that these traits are inherited and thus capable of breeding and selection.

Breeding the plants for uniformity and superior traits is a project of some magnitude but one with distinct possibilities of success. Because the staminate and pistillate flowers are separate, controlled pollination is simple. If the

tips of pistillate flower buds advanced enough to be opening the following morning are tied, the flowers cannot open and be pollinated. Artificial pollination can then be performed and the flowers bagged until the stigmas dry. Both cross- and self-pollinations have been successful, but whether or not the strain deteriorates and a loss of vigor will result from continued self-pollinations is not known. The tests of Sinnott and Bloch at New Haven (19) in the summer of 1942 disclosed that seeds were produced in all races grown by self-pollination.

It is interesting to note with reference to the practice of removing the early female flowers because of the probability that they will produce smaller fruits, that not all experience has supported this procedure. Sinnott and Bloch report successful application of growth substances, especially indole-acetic acid, on the stigmas or the tips of young ovaries before pollination and the production therefrom of fine fruits entirely free of seeds. The fruits otherwise appeared to be exactly like those of normal seeded fruits. Because removal of seeds from dried gourds is a time-consuming process, it would be worth the labor involved to employ the hormone technique to produce such a seedless type.

Literature Consulted

1. Agócsi Pál. Három új Növény Magyarországon [Three plants new to Hungary]. Agrártudomány [Agricultural Science] 4: 312–320. 1952.
2. Bailey, L. H. Some recent Chinese vegetables. Cornell Univ. Agr. Exp. Sta., Bull. 67: 177–201. 1894.
3. ———. Standard Cyclopedia of Horticulture. Vol. II, p. 1921. 1941.
4. Blasdale, Walter C. A description of some Chinese vegetable food materials and their nutritive and economic value. U. S. Dept. Agr., Off. Exp. Sta., Bull. 68. 1899.
5. Bretschneider, E. History of European botanical discoveries in China. Vol. 1: 143–144. 1878.
6. Burkill, I. H. A dictionary of the economic products of the Malay Peninsula. Vol. 2. 1935.
7. De Candolle, A. and C. Monographie Phanerogamarum. Vol. III: 456–457. 1881.
8. Howes, F. N. The loofah industry. Roy. Bot. Gard., Kew, Bull. Misc. Inf. 4: 266–270. 1931.
9. Ingram, Jean S. The luffa plant and its uses. Col. Plant & Animal Prod. 3: 165–173. 1952/1953.
10. Japanese Loofahs. The Chemist and Druggist 126: 781–782. 1937.
11. Luffas in a New Jersey Garden. Jour. New York Bot. Gard. 44: 133–134. June 1943.
12. Marañon, Joaquin M. Nutritive mineral value of Philippine food plants. Phil. Jour. Sci. 58: 317–358. 1935.
13. Merrill, E. D. An enumeration of Philippine flowering plants. Vol. 3. 1923.
14. Porterfield, W. M., Jr. Luffas as they are used by the Chinese. Jour. N. Y. Bot. Gard. 44: 134–138. 1943.
15. ———. The principal Chinese vegetable foods and food plants of Chinatown markets. Econ. Bot. 5: 3–37. 1951.
16. Reko, Victor A. Estropajo (*Luffa*), der vegetablische Schwamm. Faserforschung 13: 14–21. 1937.
17. Sherman, Hartley Embrey. Relative content of water-soluble vitamin B in thirty oriental foods. Philippine Jour. Sci. 38: 9–36. 1929.
18. ———, and Tsan Ch'ing Wang. Chemical analyses of thirty-seven oriental foods. Philippine Jour. Sci. 38: 69–80. 1929.
19. Sinnott, E. W., and Bloch, Robert. Luffa sponges, a new crop for the Americas. Jour. N. Y. Bot. Gard. 44: 125–132. 1943.
20. Stuart, G. A. Chinese Materia Medica. pp. 248–249. 1911.
21. Sylvester, Elinor F. Loofas Ahoy! For. Comm. Weekly 10: 4–5, 23. 1943.
22. Wehmer, C. Die Pflanzenstoffe. 2nd ed. Vol. II: 1195–1196. 1931.
23. Wilson, Charles Morrow. New crops for the New World. p. 286. 1945.
24. Wilson, E. H. A naturalist in western China. Vol. 2: 57. 1913.
25. Yueh Fong, and Read, Bernard E. The vitamin C content of Chinese foods and drugs. Chinese Jour. Physiol. 9: 47–62. 1935.

Pakistan Santonica

This anthelmintic drug, consisting of dried unexpanded flower heads of several species of Artemisia native to widely separated areas in both the Old and New Worlds, has heretofore been commercially obtained principally from A. Cina of Turkestan. Today A. maritima of West Pakistan has supplanted the Russian source as the principal supplier.

I. I. CHAUDHRI
Botanical Survey of Medicinal Plants, Abbottabad, Pakistan

Pakistan has become the largest santonin-producing country of the world in recent years, surpassing Russia which was previously the main supplier in the world market. *Artemisia maritima* Linn., source of santonin in Pakistan, is found wild over large barren areas of Baluchistan, Waziristan, Kurram Valley, Khyber Agency, Chitral, Dir, Swat, Kaghan Valley, Indus Kohistan and Gilgit Agency. In spite of the fact that santonin is known to be present in the *Artemisia maritima* of other places, so far it has been collected only from Gilgit Agency and Kurram Valley. In 1927, for the first time, seven tons of the drug were collected from the Upper Kurram Valley. Since then its production has been increasing, and last year's yield was expected to be over 900 tons. From the Rattu area of Gilgit Agency about 120 tons are collected annually.

Systematic Position

There is some confusion in the literature regarding the nomenclature of the plant yielding santonin in Pakistan. Gilgit Agency *Artemisia* was named *A. brevifolia* by Royle, but Hooker (1897) considered this designation a synonym of *A. maritima*. Santonin-containing *Artemisia* of Kurram Valley has been referred to as *A. maritima* forma *rubicula* by Bhadwar (1934) and as *A. kurramensis* by Qazilbash (1950). The writer has reached the conclusion that there is no justification for putting them in different species and that, at the most, they may be considered as varieties or subspecies. The only significant variation in the population is that there is a tendency to have more than three florets per head in the Gilgit plants, thus exceeding the usual number in the Kurram Valley plants.

Description

Artemisia maritima is a perennial herb with a deep, well-developed, persistent tap root. From the root stump fresh branches sprout in spring after the snow begins to melt. It flowers from August to September, and the seeds mature from October to November, depending on the altitude, after which the aerial parts die. The branches are erect, woody at the base, with colour varying from different shades of purple to green. The leaves are very much dissected with linear segments and have various shades of green, depending on the tomentum. The number of florets in a head varies generally from three in the Baluchistan, Kurram and Waziristan specimens to over 14 in some specimens of Kaghan Valley and Gilgit Agency. The colour of the flower

FIG. 1. *Artemisia maritima* growing on the ridges of a garden at Parachinar, Kurram Valley, Pakistan.

FIG. 2. A field where *Artemisia* was previously only on the "bunds" but where new seedlings have been transplanted on the ridges in the field recently.

varies from yellow to purple. By the time flowering starts, most of the leaves have fallen from the branches.

Ecological Observations

Artemisia maritima is restricted to those regions which have pronounced winter rains or snow-fall and which are not much under the influence of summer monsoon rains. It is one of the pioneer plants which like stony places, and soil erosion seems to help its spread. Because of its strong and deep tap root it can thrive on the soil moisture percolating down during winter rains or after melting of snow. It grows pure over large areas between the altitudes of 5,000 and 14,000 feet, and in these regions few other plants can compete with it. The seeds seem to have no dormant period and appear to germinate immediately after the first winter rain. Thus they make the best use of the winter rains and are well adapted to the regions where *Artemisia* dominates.

Cultivation

In Kurram Valley the drug is no longer collected from the wild but is cultivated as a regular crop, mostly on the "bunds" of the cultivated fields (Fig. 1) and in some cases on the ridges in the fields which are not well suited for other crops (Fig. 2). Cultivation is carried out in the upper Kurram Valley villages of Bughdi, Sahrakali, Lalmi Burki, Kachkine, Karakhela, Kharlachi, Shingah, Kunjalizai, Nastikot, Shalozan and Parachinar.

Seeds are sown in well-prepared slanting beds in February, and seedlings are transplanted next year from December to February on the "bunds" or ridges at a distance of about two feet. Once they become established they continue to yield a good crop for a number of years. Two hoeings are generally given every year, and plants seem to do well even without any manure. As a result of selfing experiments carried out by the Agriculture Department, a number of high santonin-containing strains have been evolved, out of which B-3 and B-9 have been found to contain 3.17% and 4.24% of santonin, respectively. Seeds of these are now being distributed to the cultivators.

FIG. 3. *Artemisia maritima* growing wild in the Rattu area, Gilgit Agency, on barren hill with rocks exposed as a result of erosion.

Artemisia maritima is not cultivated in the Gilgit Agency and the drug is collected from wild sources from the Rattu area in the Astore sub-division (Fig. 3). It is found on the Rattu, Rampore, Chourit, Maich, Dadu Jail, Phubind, Chawroot, Gurial, Faqui Koot, Gunai, Chlugam, Pragot, Zaipur, Dirli Pain and Dirli Bala hills.

Collection and Curing

In Kurram Valley collection and curing of the drug have been organised by the Agriculture Department. The aerial parts of the plant are cut at ground level

from August to September by the grower when the plants are in the unopened floral bud stage. This stage has been found to contain the maximum percentage of santonin. The harvested crop is brought to the thrashing floor at the collecting centre and is handed over to the staff of the Agriculture Department employed for this purpose. It is dried in the open sun and then thrashed under the feet of bullocks and donkeys. As soon as the floral buds and leaves are detached from the branches, the thick stem portions are removed by manual labour. The remaining material is passed twice, first (*a*) through sieves of 16 mesh per square inch, then (*b*) of 25 mesh, and lastly (*c*) of 64 to 100 mesh. The product obtained through the finest sieve is classed as "A" grade. That which fails to pass through sieves *b* and *c* is thrashed again and is classed as "B" grade. It contains various proportions of floral buds, pieces of leaves and small branches. "A" grade contains more floral buds than "B" grade, and 1.5 to 2.5% of santonin as compared to 0.8% to 1.5% in the "B" grade. From various collecting centres the drug is brought to Parachinar in gunny bags and is stored. After determining the price on the basis of santonin percentage, the stuff is despatched to the factory at Rawalpindi where santonin is manufactured by extraction of the santonica.

The Gilgit Agency *Artemisia* is leased on an annual basis, and manual labour is employed to pluck the tips of the branches to about three inches. The collection season generally lasts from the middle of June to the end of July. The drug from this area consists mostly of leaves and tender portion of the branches, not so much of buds as from other areas. The percentage of santonin varies from 1.0 to 1.5.

Summary

Pakistan has become the largest santonin-producing country of the world with a present annual production of over 1,000 tons and potentialities of producing unlimited quantities of the crude drug from *Artemisia maritima*. The plants are found wild over large areas in West Pakistan, and others are cultivated on the "bunds" of cultivated fields in the upper Kurram valley. In the Rattu area of the Gilgit Agency, collection is only from wild plants.

The plants are harvested in the unopened floral bud stage and are graded into "A" and "B" in the Kurram valley. The santonin percentage varies in "A" grade from 1.5 to 2.5, in "B" grade from 0.8 to 1.5. Gilgit *Artemisia* is collected in the leaf stage and contains santonin from 1.0 to 1.5%.

Literature Cited

1. Badhawar, R. L. 1934. Report on the Kurram *Artemisia* from the santonin standpoint. Delhi.
2. Hooker, J. D. 1897. Flora of British India. Vol. III, pp. 323–324.
3. Qazilbash, N. A. 1950. A new species of *Artemisia* from Kurram Valley. Jour. Indian Bot. Soc. 29: 190–194.

Olive-Growing in Greece

This industry, which may be 3,000 years old, today is first in world production of preserved olives, harvested from over 50,000,000 trees.

ARNOLD KROCHMAL[1]
Associate Professor of Horticulture, Arizona State College, Tempe

The olive (*Olea europaea* L.) has a long and venerable history in Greece, and was mentioned as early as 900 B.C. by the Greek poet Homer.

Around the introduction of the olive into Greece have grown a number of legends. One credits Hercules with having brought the tree on one of his expeditions back to his homeland; another more colorful story claims that Neptune and Minerva quarreled over the naming of the city of Athens, and that the council of the gods decided that the deity who gave mankind the most valuable gift would have the honor of naming the city. Neptune, so the story goes, struck the shore and up sprang a war-horse; Minerva in turn produced an olive tree and was judged the winner because the council felt that peace, symbolized by the olive branch, was more useful to man than war, symbolized by the horse.

The high regard in which the ancient Greeks held the olive is attested to by the legend that one grew within the precincts of the Acropolis in Athens in the second century A.D.

Today Greece stands first in the world in production of preserved olives, and third in olive oil production, after Spain and Italy.

In 1947 the Food and Agricultural Organization of the United Nations[2] reported the number of olive trees in Greece in 1939 at about 11,000,000. This number is apparently very inaccurate, for the International Institute of Agriculture[3] claims that in 1929 there were between 30,000,000 olive trees, if official figures were accepted, and closer to 60,000,000 trees if the total yield of oil is divided by an average yield of oil per tree.

During the German occupation of the second World War new plantings were kept at a minimum, although no large-scale destruction of trees occurred. However, production dropped because of the difficulty in caring for the trees properly in those regions where such care had been the custom. Production of the trees is variable, depending, of course, on variety, soil fertility, attacks of the daucus fly, age of tree and irrigation. Under dry-farming conditions trees produce from 20 to 40 pounds per tree; under irrigation, from 65 to 85 pounds per tree. The oil content varies from 20% to 35%[2].

The importance of the olive crop to the Greek economy can be judged when it is noted that olive trees, according to the FAO, occupy 27% of the total agricultural area and produce 11% of the total exports. In Greece's never-ending struggle for economic stability, sources of foreign exchange are doubly valuable.

The adaptable nature of the trees permits them to be grown in soils of high lime content and on rocky hills unsuited

[1] Formerly Fulbright Agriculturist, Salonika, Greece.

[2] Report of the FAO Mission for Greece. 1947.

[3] Olives and olive production. Int. Inst. Agr. 1940.

FIG. 1. Harvesting olives in Greece is a village enterprise, one of the times when the men work as actively as do the women. Children tag along and play under the trees.

FIG. 2. The crop is moved in bushel-size baskets. The head-gear worn by the girl is used during the warm part of the year, and in winter is often replaced by a similar article, but of a darker color.

for other crops, two very desirable features in a country so largely unsuited for crop production because of low soil fertility.

Unfortunately, although there are high yielding varieties that would increase production, the poverty of the peasants in general prohibits tearing out old groves and replacement with new trees because of the time lag in production of young-bearing trees. There would be a period of from five to seven years of low yields while the young trees matured. Young trees bear after two years, but not in any significant amount until about six years of age. Alternate bearing is a problem, caused, the peasants claim, by harvesting too late in the season.

The important olive groves in Greece are all located around Athens, on the Peloponnesus and on the Aegean and Ionian islands as well as on the southern part of the mainland.

The period of fruit maturation is rather long, extending from October to January; the harvest, however, is usually finished between November and December. Gathering the fruit is done by one of three methods—beating the trees with sticks, natural shedding, and hand picking as illustrated in the accompanying photos.[4]

The fruit is one of the staples of diet, ranking with bread and cheese, and it is a common sight to see peasants eating lunch of these items in the field.

FIG. 3. A rather brief inspection is made of the fruit to remove the more obviously damaged and diseased olives in the field.

[4] Photos courtesy Mutual Security Administration, Greece.

In order to encourage olive production the FAO has made the following suggestions as means of increasing both yield and quality:

a) elimination of low-yielding trees and those producing inferior fruit,
b) use of irrigation where possible,
c) increased use of fertilizers,
d) elimination of hand labor in cultivation, introduction of machinery where possible,
e) scientific pruning program,
f) systematic measures to control diseases and insects,
g) improved methods of harvesting and handling crop,
h) adoption of modern and improved methods of processing crop.

The most important varieties and their characteristics are [3]:

Coronaiki—small fruit (1 gram), wide soil adaptability, low oil yield of high quality.

Daphnoelia—small fruit (2 grams), adapted to poor soils, good yields.

Methonia (*Mouratolia*)—small fruit (1.5 grams), high yields, good quality oil.

Corfolia—found near salt water, high fruit yield, high oil yield.

Smertolia—small fruit (1 gram), wide adaptability to soils, high yield and high quality fruit.

Agouromanacolia—medium sized fruit (2.5 to 3 grams) resistant to cold, high yield, good quality.

Mastoidis micra—small to medium sized fruit, resists low temperature, grows at the upper limits of cultivation, 3000 feet, high yield, good quality.

Mastoidis megallus—average fruit (2 to 3 grams), oil of good quality.

Adramittini—average fruit (3 to 4 grams), fine oil.

Megaritiki — (*Ladonia*) — average fruit (3 to 4 grams), fair preserves, some oil.

Valanolia—average fruit (3 to 4 grams), ripens late, high yield of fruit, good oil yield of high quality.

Throumbolia—large fruit (up to 5 grams), oil content high.

Carydolia—fruit large (4 grams), excellent for tanle olives, oil of good quality.

Adrocarpos—large fruit, used for preserves, grows in profusion.

Vassiliki—extremely large fruits (up to 12 grams), preserves and oil.

Stravolia—large fruit (up to 5 grams), direct consumption for oil.

Amygdalolia—large fruit (5 to 8 grams), good quality, green preserves and oil.

Propagation of Black Pepper

Studies show that black pepper can be propagated rapidly by leaf cuttings, the results far exceeding those obtained by conventional methods. An innovation in the use of leaf cuttings is also described in this study.

JOHN L. CREECH *

The successful introduction of black pepper (*Piper nigrum* L.) into America has provided material for an interesting and productive propagation study. During recent years the U. S. Department of Agriculture, through its Section of Plant Introduction, has obtained seed and cuttings from pepper-producing centers in the Old World. All this material has been sent to the U. S. Plant Introduction Garden, Glenn Dale, Maryland, for quarantine propagation. This has permitted a comparative study of the method used by propagators in India with those to which we are accustomed in this country.

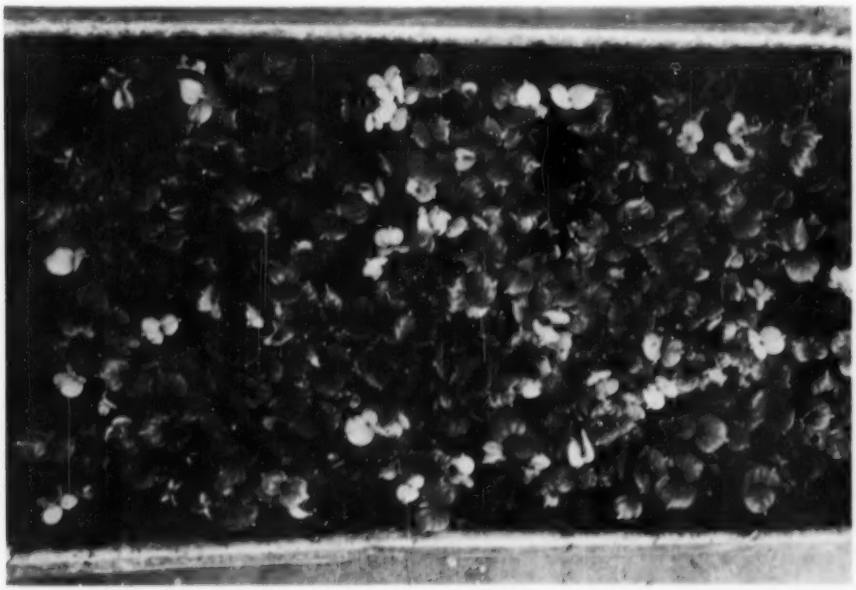

FIG. 1. Seedflat of Kal-Balamcotta variety of black pepper, showing germination after one month. Note albino seedlings. P.I. 214301.

From a series of abstracts, by Greene (1), of articles pertaining to pepper culture, a fairly complete picture of propa-

* United States Department of Agriculture, Agricultural Research Service, U. S. Plant Introduction Garden, Glenn Dale, Maryland.

gation methods in vogue in pepper-producing countries can be obtained.

Usually woody cuttings up to two feet in length are stuck into the ground around the bases of shade trees, or occasionally the cuttings are rooted in the open in shaded nursery beds. Rooting is slow, and after several months only a small percentage of rooted cuttings can be expected. Survival is reported in some instances to be as low as five percent. Sometimes mound layering or marcotting is resorted to; and in the case of the Trang pepper, propagation is by underground rhizomes. Seedlings are not used to establish plantings, and there are only a few published accounts on germination. These range from observations wherein germination was rapid and the percent high to those which describe the process as slow with the yield low.

Here at Glenn Dale we have found that black pepper seeds sown in sphagnum moss usually germinate in a month but that there is considerable variation in the percent of germination. Fresh seed has given a germination of about 80 percent. The seedlings from seed obtained from cultivated plants are fairly uniform, but one introduction (P.I. 214300) obtained in the wild at the extreme cold limit of climatic adaptation for pepper produced only seedlings which are stunted and have coarse deformed leaves. The most unusual observation was that made in a seed introduction (P.I. 214301) obtained from the variety Kal-Balamcotta. This is a hybrid between the two leading varieties, Kalluvalli and Balamcotta, and is said to possess the attributes of both parents. Germination of the seed was exceptionally high, but one-fourth of the seedlings were albino, indicating that the parent plant is heterozygous for this factor. The seedlings of Kal-Balamcotta are shown in Fig. 1. In addition, one seedling has variegated green and white foliage that is highly ornamental.

The only major difficulty encountered in the introduction of clonal pepper material has been the low survival of the cuttings following shipment. Even when cuttings are packed in polythene bags, and transit time is reduced to four or five days, mortality is very high. It is this factor that undoubtedly accounts for there being so few named pepper varieties in experimental plantings in this hemisphere.

Typical of the introduction and propagation methods adopted for black pepper is the procedure used for a shipment of cuttings that arrived at Glenn Dale for quarantine in January, 1953. This shipment consisted of 199 cuttings of the varieties Balamcotta (P.I. 205364) and Kalluvalli (P.I. 205365). These were typical Indian cuttings, not quite so long as would normally be used, but they consisted of three or four nodes and were 12 to 16 inches long. The cuttings were treated with a rooting compound (IBA, 8 mgs./gm. talc) and stuck in a closed sandbed with bottom heat and a high humidity. Despite these seemingly ideal conditions the cuttings were slow to root. The first ones were potted after two months, while the remainder had to be kept in the propagating bed until the following July. In all, only 29 cuttings (15%) rooted; this percent agrees fairly well with the results obtained by Indian propagators. These first plants were potted and grown as a source of material for further propagation.

In order to accelerate the program, a more rapid and productive method was required. Pepper vines develop aerial roots at every node, and if these reach the ground, they continue to grow and function as normal roots. Therefore single-node cuttings were regarded as the most promising to try. In a closed propagating case with low light intensity and high humidity, single-leaf cuttings rooted 88% in seven to 14 days. A larger number of these nodal cuttings were then

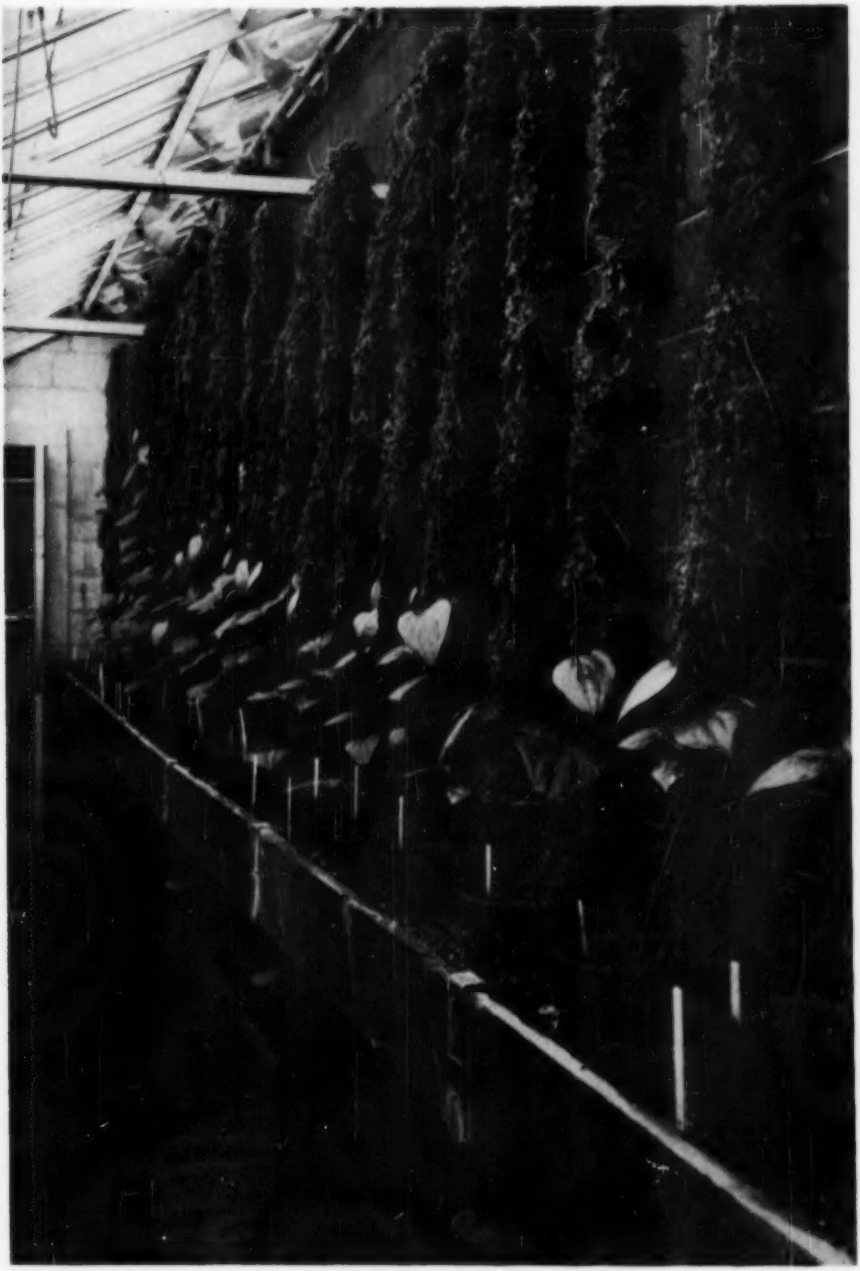

FIG. 2. Pepper stock plants attached to sphagnum-mossed bamboo poles. Many of these plants are the original cuttings, and the length of the internodes can be noted. P.I. 265364–365.

FIG. 3. An individual leaf showing the mass of roots which have penetrated from the node into the sphagnum moss. P.I. 205365.

taken from the stock plants and rooted to increase further the material available for planting.

Because of the time lag required for the stock plants to reach sufficient size to produce enough cuttings, a simple innovation was adopted. Bamboo poles were covered with damp sphagnum moss and placed behind each plant, as shown in Fig. 2. At first the plants had to be tied to the poles, but, as the roots developed and penetrated the moss, they secured the vines to the poles. The only additional cultural requirements were syringing the sphagnum on the poles and occasionally applying a liquid fertilizer to the sphagnum. As the plants grew, each node rooted into the moss so that when the vines reached the top of the poles, each prospective leaf cutting was heavily rooted, as shown in Fig. 3.

The vines were then cut back to the lowest three leaves, and the rooted nodal cuttings separated and removed from the moss. Fig. 4 shows one of the rooted nodal cuttings. These were potted in soil and placed on the open greenhouse bench in a shaded house. Within six weeks the newly potted cuttings possessed leaders which had developed from the axillary buds. Of 201 cuttings rooted, 189 (94%) were successful, as shown in Fig. 5, photographed April 1, 1954. The rapid development of these young plants can be determined from Fig. 6, photographed May 27, 1954, about 57 days later. Already these new plants had a complement of rooted nodes ready to be removed as cuttings. On the stock plants which had been reduced to three leaves when the cuttings were removed, new leaders developed immediately, and these plants exceeded the new cuttings in height because of the heavy root system already established. The developing buds in the leaf axils of a stock plant are shown in Fig. 7. With all of the peppers grown so far, these buds remain dormant until terminal growth has been stopped.

FIG. 4. A pepper leaf-cutting after it has been cut from the stock plant. Because of the consistency of the sphagnum, the cuttings are easily removed without the loss of roots. P.I. 205365.

Shortly before another set of cuttings was to be removed from the plants, the introductions were shipped to the Federal Experiment Station, Mayaguez, Puerto Rico. To accomplish this, the vines were first pinched to stop further terminal growth, and a few days later they were removed from the sphagnum supports. This involved merely dislodging the roots with some of the moss attached. The vines were packed in florists' cartons lined with polythene film and were covered with sphagnum moss, as shown in Fig. 8. The plants were

FIG. 5. The leaf-cuttings are immediately potted and placed in a shaded greenhouse. These cuttings were photographed on April 1, 1954. P.I. 205364–365.

FIG. 6. Pepper vines from single-leaf cuttings growing on sphagnum-mossed poles. These plants are the same ones shown in Fig. 5 but photographed on May 27, 1954, 57 days later. P.I. 205364–365

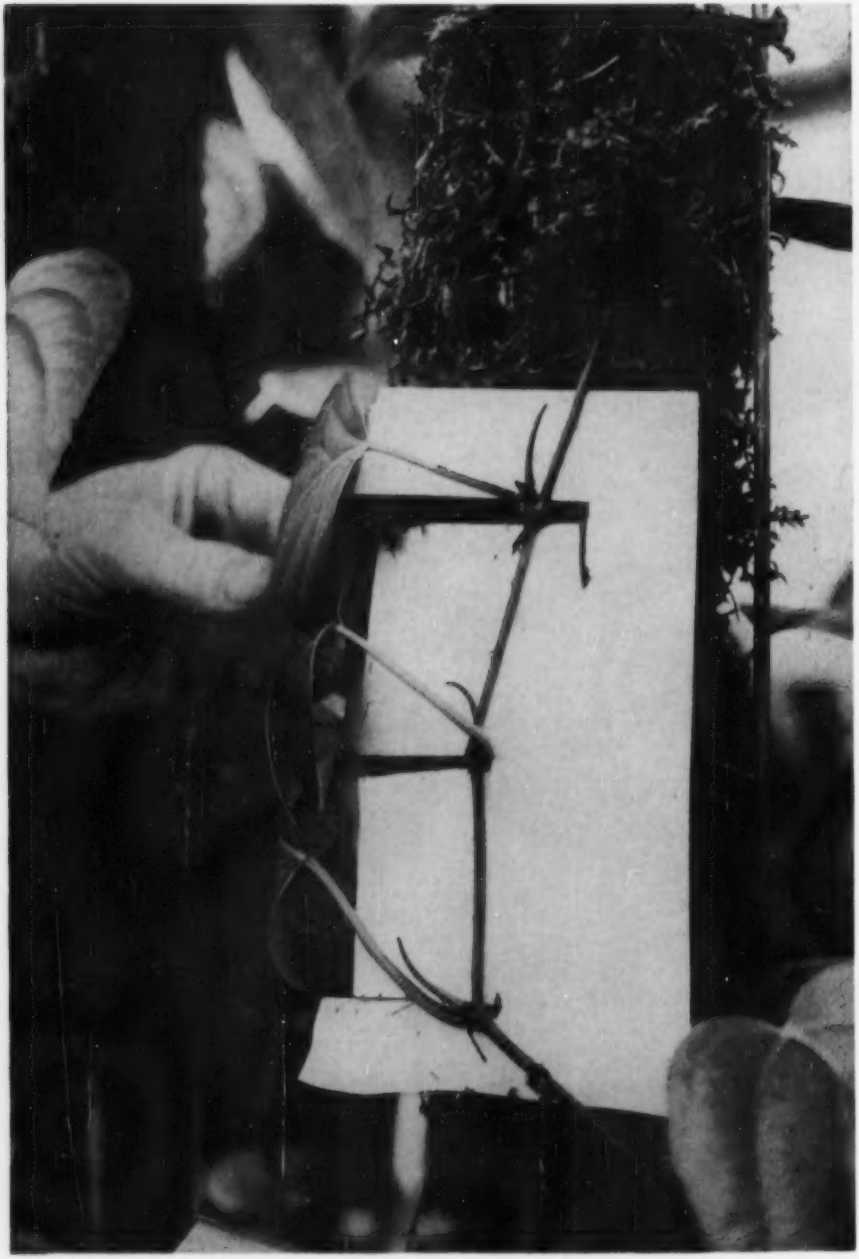

FIG. 7. Cut-back pepper vine showing the new leaders that develop shortly after the rooted cuttings have been removed. P.I. 205365.

FIG. 8. Preparing pepper vines for air shipment. The vines with their stem-roots attached are packed in sphagnum moss and the carton is lined with polythene film. P.I. 205364–365.

then shipped by air in heated compartments, and, on arrival at their destination, the rooted cuttings were removed from the stock plants and potted.

Although the method described here was designed to meet the initial propagation demand where a limited amount of stock was available, the same method could be employed in a field program. The stock plants would be grown in a lath house and allowed to climb on sphagnum-mossed bamboo poles. When the desired number of cuttings had been attained, they could be removed and with careful technique planted directly into the field. The chief advantage of the sphagnum method over the use of unrooted leaf-cuttings is in eliminating the care needed during the rooting period. Certainly the sphagnum method would far exceed the age-old method of planting the unrooted cuttings in situ. Regardless of whether the sphagnum method described here is used or nodal-cuttings are rooted in propagating beds, it appears that the results with single-leaf cuttings far exceed those obtained with the long semihardwood cuttings that have been used by pepper growers for centuries. It may be concluded that the low yield obtained by growers in India with their propagating stock is due to the kind of propagating wood used, not so much to the propagating conditions. At the time that this paper was prepared (October, 1954), cuttings received from India and put in sand beds the previous February were still unrooted, while individual nodal-cuttings about two months old were already growing and had been attached to sphagnum-mossed poles for further propagation.

(The writer acknowledges the photographs taken by Mr. W. O. Hawley, of the staff of the U. S. Plant Introduction Garden, Glenn Dale, Maryland.)

1. Greene, L. 1951. Abstracts of some articles pertaining to the cultivation of black pepper. U. S. Dept. Agr., OFAR, Tech. Collab. Br. 45 pp.

Utilization Abstract

Vegetable Sweets Native to the U.S.A. Apart from sugar maple (*Acer saccharum*) and black maple (*A. nigrum*), both of which have long been the pioneer and more recently the commercial sources of maple sugar in the United States, no other native plants have served as important agencies in providing sweetening material. Minor sources, serving more as novelties, have been the sugar pine (*Pinus lambertiana*) of California and Oregon which, when cut into or injured, exudes a sap which forms a sweet and edible but resinous substance; the balsam fir (*Abies balsamea*) of northeastern North America which, too, exudes a sweet chewable gum; common reed (*Phragmites communis*), the wounded roots of which exude a sweet pasty substance; and sweet, or red, gum (*Liquidambar styraciflua*), which also, when injured, forms a resin or gum that has been used as a substitute for storax, commercially obtained from two other species of *Liquidambar* growing in southeastern Asia and formerly used in medicine.

Toxicological Studies of Southeastern Plants. *I. Leguminosae*

Only four of the 22 species examined in this family displayed toxicity, as tested against chicks and/or mice.

WILBUR H. DUNCAN, PAUL L. PIERCY AND ROBERT J. STARLING
Department of Botany and School of Veterinary Medicine, University of Georgia, Athens, Georgia

Introduction

The knowledge that certain plants possess toxicity to animal life is not new. History records that many such plants were used by early civilizations in the preparation of various crude medicaments to be administered to produce relief from numerous maladies suffered by man and animals. Since these early observations, and especially in the last half century, accrued information has added much to our concept of the poisonous plant problem and of certain medicinally active principles contained in such plants.

Various poisonous plants occur in southeastern United States, and their toxic effects upon certain animal species are recognized (4, 6, 8, 9, 12, 17). In addition, many species related to known poisonous plants in this area and/or to poisonous species existent elsewhere are also to be found. Little or no information as to possible content of alkaloids, glucosides or other active principles and as to possible effects of such related plants upon animal life is available.

With this realization a study of numerous plants in southeastern United States, botanically related to recognized poisonous species, has been undertaken. In this study acute toxic effects upon laboratory animals under experimentally controlled conditions have been under survey. Although the findings are largely of a basic nature, they indicate possibilities for investigation of previously unexplored potential sources of medicinally active plant materials and enlarge upon toxicological knowledge of clinical value to veterinarians and others.

Experimental Methods and Procedures

Materials used for experimental feedings were collected in the southeastern States from areas in which the respective plants were growing wild. As suitable plants were located, portions desired for use in experimental animal feeding were collected and packed in plastic bags which were inserted in cardboard freezer cartons. The cartons were next placed on dry ice in a 200-pound dry ice shipper (Shamrock #624) within a minute from the time the plant material was packed. It was thus maintained in the frozen state until the collections were returned to the laboratory at the University of Georgia. At the laboratory the cartons were transferred to a deep freeze cabinet and held at about – 5° F.

To facilitate documentation of samples used for experimental feeding and to provide adequate identification at any time, specimens were selected, pressed, dried and filed in the Botany Herbarium at the University of Georgia.

When plant material was desired for experimental feeding, an adequate sample was removed from the respective

carton and plastic bag and placed loosely in a sealed glass jar. When thawed, the material was spread thinly in an electric drier at about 60° C. for 12 to 24 hours. Loss of weight during drying was not determined. The dry material was ground by means of a Wiley Mill to 20-mesh size. Some materials were ground finer, those used for feeding mice being run through an 80-mesh screen. The ground materials were then stored in sealed glass jars until used.

The above procedure applies specifically to plant materials collected in 1952 and identified by collection numbers 13382 through 14750. Specimens collected during 1953, and identified by collection numbers 14751 through 17453, were not frozen but placed loosely in coarsely woven cloth sacks until night when they were dried over an electric drier. Otherwise they were treated in the same manner as frozen collections.

The procedure of study for each plant was designed to explore the possible presence of toxic properties by attempting to demonstrate acute toxic effects upon respective animals experimentally maintained under controlled conditions. Possibilities of cumulative toxic effects and effects caused by mechanical injury were not given specific attention. The non-poisonous plant material used concurrently for comparison purposes was alfalfa which had been collected, handled and fed in ways identical to that employed for plants of unknown toxicity used in the study.

Two animal species, namely white mice (Carworth Farms number 1 strain) and white leghorn chicks, have been employed in the study. Both are well adapted to the laboratory conditions under which the experiments were conducted. They are further advantageous in that they can be experimentally maintained and studied in greater numbers at less expense than larger laboratory animals. Male white leghorn chicks are especially inexpensive. Furthermore, much less plant material is needed for testing with these smaller animals than larger ones. More plant species and/or plant parts, therefore, can be run experimentally on an equivalent over-all total of collected plant materials. Materials of a number of small and/or scarce plant species which are included in this study could not have been obtained in sufficient amounts for tests with larger animals without spending several man-days collecting each species. Results indicate that chicks are probably better adapted than mice, chiefly because their relatively larger size facilitates a clearer gross picture of symptoms and lesions. Also, relatively larger amounts of plant material may be fed to the chick. While the earliest studies herein reported were made with mice, use of chicks has completely dominated and replaced mice in our screening studies. When and if the active toxic principles are detected and eventually isolated in sufficient quantities for experimental animal testing, it is felt that mice or rats may then become the experimental animals of choice.

Forced feeding procedures with carefully weighed quantities of plant materials were used for all experimental animals. Prior to experimental feedings the normal ration was withheld from all animals to be used for 12 hours, but fluid intake was not restricted at any time. For mice a stomach tube method was devised and employed successfully.

This method involves a carrier prepared by macerating several fresh or frozen pods of okra with an equal weight of water. The resultant material is strained through cheese cloth to remove materials such as lignin and cellulose. Plant material ground to 80-mesh so as to be capable of passing through a 20-gauge needle is suspended in the okra carrier in a ratio of five parts okra solution to one part dried plant material.

A stomach tube made of polyethylene

tubing (3.8 French) measuring 6 cm. in length is fitted snugly over the shaft of a 20-gauge needle. In using such a small needle, considerable pressure is required to void the syringe of the plant suspension; hence the lock type syringe is preferred.

The stomach tube is passed along the curvature of the roof of the mouth of a lightly etherized animal (Fig. 1) until the esophagus is reached. At this point much care must be exercised to insure intra-esophageal rather than intra-tracheal entrance. The esophagus will accommodate the tube with ease until the cardiac sphincter is reached. Here gentle agitation affords easy entry into the stomach. When proper passage has been accomplished, the needle attached to the polyethylene tubing will be at the level of the mouth (Figs. 2 and 3). The syringe containing the plant suspension is next attached to the needle and the desired quantity (usually 0.75 cc) injected (Fig. 4). It must be pointed out that feedings must be rapid, as imbibitional activity in the material often brings about changes which prevent its passage through the needle.

This technique has been used successfully with many different plant materials and with mice as small as 18 grams. A few plants have been encountered which could not be fed by this technique largely because they could neither readily nor satisfactorily be held in suspension sufficiently long to permit uniform and unobstructed passage through the 20-gauge needle used for connecting the polyethylene tubing with the administering syringe.

All chicks used have been obtained from the same hatchery as day-old males. They have been held in brooders and fed a starting mash ration until their weights reached 60 to 294 grams, at which time they were of an age and weight suiting the needs of the experiment. They were carefully selected and caged in groups of five for each test feeding with as close uniformity as possible in weight. Similar groups were selected for use as control birds.

Dried plant material, ground to 20-mesh size, was packed in number 00 gelatin capsules. From one to four such capsules represented the dosage which was massaged into the crop. With some plant materials, packing of the dry mass in the crop occurred after the gelatin capsule had dissolved, under which circumstances moisture was added by forcing water into the crop by means of a syringe and rubber cannula. The additional fluid facilitated softening and dilution of the mass and its passage from the crop. In normal chicks, allowed to feed at will from normal rations, the content of the crop after full feeding was found to equal from six to eight percent of the body weight. That amount of encapsulated, ground, dry plant material could not be administered without overpacking the crop. With more dense plant materials it was difficult to administer an amount equalling more than 2.5 percent of body weight, and with plant material of low density, to exceed an amount equivalent to 1.5 percent of body weight. Thus it may be concluded that the capsule method of forced feeding is valid only if and when greater amounts are not required. With many known toxic plants, amounts equivalent to 1.5 percent or less of body weight are sufficient to produce toxic effects (9).

Attempts were made to feed dried, ground, experimental material of several species by mixing it with regular rations and making the mixture available to the animals. There was little success with this method, even when special containers designed to prevent loss of the material being fed were used. Animals ate varying amounts, sometimes almost none, of most materials. Occasionally a certain ration was left practically undisturbed by one animal and scattered

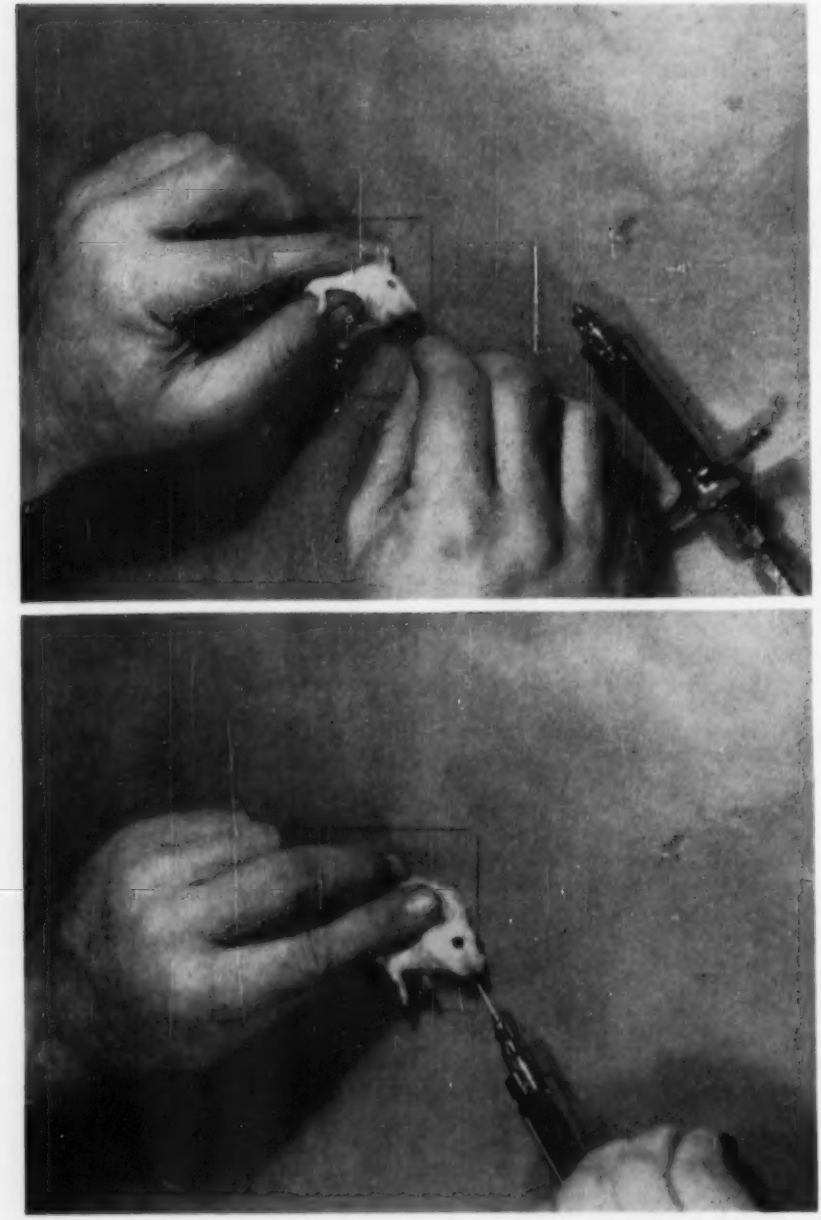

FIG. 1 (*Upper*). Stomach tube being passed to stomach of lightly etherized mouse. Method of holding animal is important.

FIG. 2 (*Lower*). Position of tube and needle in relation to mouth at time of force feeding.

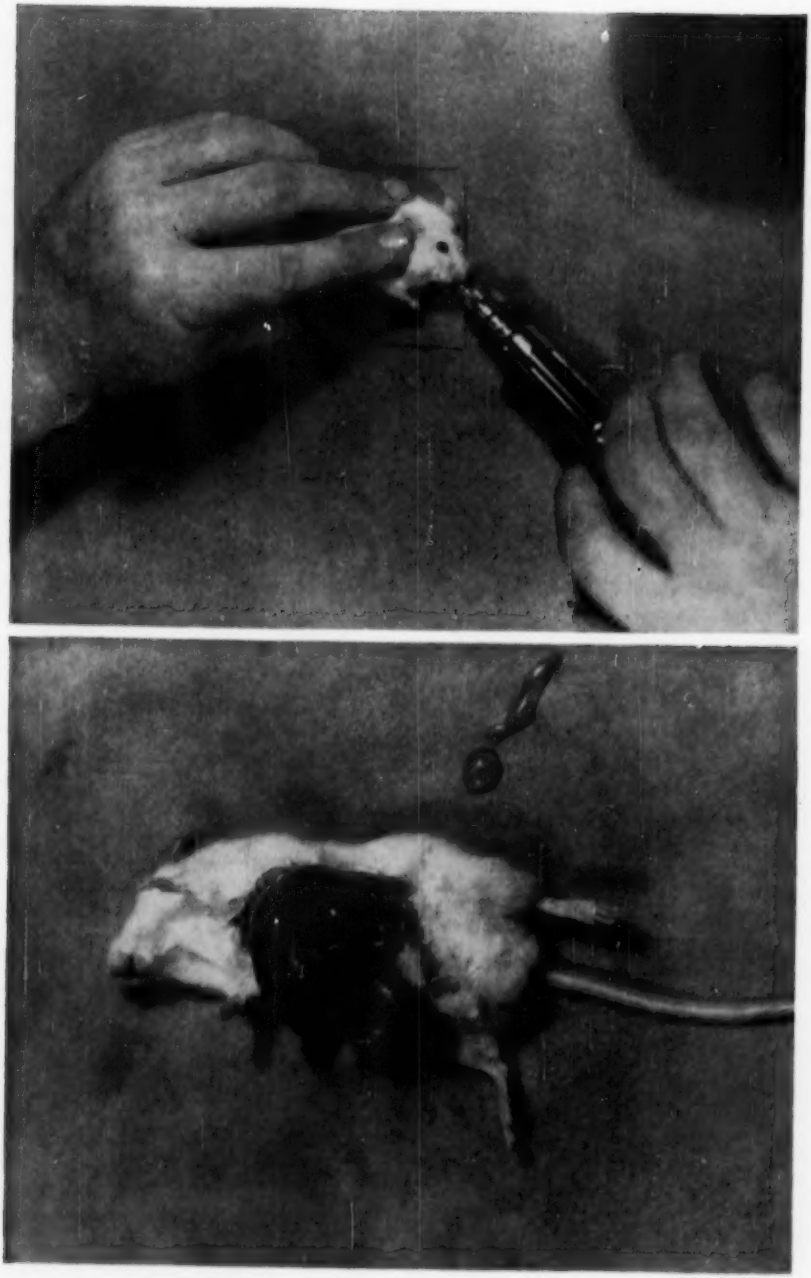

FIG. 3 (*Upper*). Tube and needle passed too deeply.
FIG. 4 (*Lower*). Mouse after feeding killed by ether and with autopsy made to demonstrate presence of experimental material in stomach.

about the cage by another. These activities were interpreted to indicate that most experimental materials were distasteful to the animals, especially since a mixture of regular rations and control material (alfalfa) was usually consumed at a uniform rate and with little scattering. No observations of toxic manifestations were made, and the method of feeding was discontinued in favor of the force feedings in which more accurately measured amounts could be given.

Animals fed experimentally were closely observed to detect changes indicative of acute toxic manifestations. These observations included general appearance, character and rate of respiration, excretions and discharges from body openings, eye abnormalities, appetite, physical activity and related features. Body temperature was rectally determined to provide nearer complete records for chicks, but a satisfactory method for determining body temperature of the mouse was not developed. Heart action was determined for both mice and chicks by the use of the cardiovibrometer as developed by Odum (10).

For those animals in which toxicity proved lethal, necropsy examinations were made. Chick autopsies were accomplished satisfactorily without magnifying aids, but to adequately determine the details and extent of lesions in mice, necropsy studies were made under illuminated, low magnification (1.1 ×).

The plant material studied was of a number of families. Only the results of our studies with Leguminosae are presented here; those with other families are to be in subsequent articles.

Toxic Species

Among the Leguminosae are several genera in which one or more species have been reported (9) to be toxic for animals. These genera include *Lupinus*, of which at least 12 species are toxic and cause lupinosis in sheep, cattle and horses; *Astragalus* (11 species) and *Oxytropis* (3 species) which cause locoism in horses, cattle and sheep; *Lathyrus* which produces lathyrism in horses, cattle and swine; *Daubentonia* (coffee-bean); *Robinia* (locust); *Crotalaria* (rattle-box); and *Baptisia* (wild indigo). Various related Leguminosae, about which little or no information regarding toxic properties is found in literature, were collected in 1952 and 1953 and routinely studied in the laboratory. These Leguminosae are enumerated in Table I together with important synonyms, common names, general statements of ecology and distribution, collection numbers, plant parts collected and fed, experimental animals used, animal weights and amounts of plant material fed (expressed as percent of body weight of the experimental animals). Locations from which collections were made and other data for all experimental plant collections are tabulated on herbarium specimens on file in the University of Georgia Herbarium.

The four specific plant materials in Table I which produced toxic manifestations in experimental chicks and/or mice were: *Astragalus michauxii* leaflets, collection number 15865 from open pine-oak woods in Toombs County, Georgia; *Daubentonia punicea* seeds and leaflets, collection numbers 13815 and 14651, from sandy pineland and roadside in Tattnall and Evans Counties, Georgia; *Glottidium vesicarium* seeds, collection by Carlton, and seeds and leaflets number 13991, from roadside and low pineland in Decatur County, Georgia; *Lupinus cumulicola* leaves, collection number 14022, from dry, sandy soil in Lake County, Florida. Brief descriptions of these four species follow so that application of the results may be made by the reader. Literature at present provides very little of this information in a form that is available to most persons and that can be used without considerable expenditure of time.

TABLE I

LIST OF LEGUMINOSAE STUDIED FOR TOXIC PROPERTIES, TOGETHER WITH DATA ON GENERAL ECOLOGY AND DISTRIBUTION, NUMBER OF COLLECTION AND PLANT PART FED, AMOUNT OF PLANT MATERIAL FED EXPRESSED AS PERCENTAGE OF BODY WEIGHT OF EXPERIMENTAL ANIMALS, AND ANIMAL SPECIES USED WITH WEIGHTS IN GRAMS

Scientific and common name General ecology and distribution	Collected number [1]	Plant part fed	Equivalent % of animal body weight	Animal and weight in grams	
Astragalus michauxii (Kuntze) Hermann [*A. glaber* Michx., *Tium michauxii* (Kuntze) Rydb.] "Loco, Poison Vetch" Sandhills and dry pinelands. Coastal Plain. Fla. to N. C.	15865 15865	Leaflet Leaflet	1.65–1.67 1.83–1.92	Chick Chick	102–105 80–84
Baptisia alba (L.) Vent. "White Wild Indigo" Rich, open woods and sandy pinelands. Piedmont and Coastal Plain. Eastern Va., south to Fla.	13761	Leaf	1.94–2.00	Chick	60–62
Baptisia albescens Small "Spiked-indigo" Woods. Central Ga. to Coastal Plain of S. C., north to Tenn. and N. C.	13566 13566	Blade Blade	2.91–3.30 0.46–0.56	Chick Mouse	62–70 27–33
Baptisia arachnifera Duncan Sandy pinelands. Wayne and Brantley Counties, Ga.	13687	Leaf	2.09–2.24	Chick	69–75
Baptisia bracteata Muhl. "Cream Wild-indigo" Woods. Eastern Ala. to Southeastern N. C.	13546 13546	Blade Blade	0.46–0.56 1.93–2.09	Mouse Chick	27–33 63–69
Baptisia leucantha T. & G. "Wild-indigo" Open prairies and woods. N. Fla. to N. C. and Ohio, west to Neb. and Texas	13736	Leaf	1.40–1.57	Chick	60–67
Baptisia perfoliata (L.) Br. "Cat-bells or Gopher-weed" Sandy soils. Central Fla., Ga., and Central S. C.	13573 13573	Leaf, flower Leaf, flower	0.46–0.56 2.96–3.18	Mouse Chick	27–33 66–71
Crotalaria angulata Mill. [*C. rotundifolia* (Walt.) Poir.] "Rattle-box or Rabbit-bells" Dry woods, sandy pinelands. Piedmont and Coastal Plain. Fla. to La. and Va.	13734	Leaf, flower, fruit	0.98–1.11	Mouse	36–41
Crotalaria maritima Chapm. "Rattle-box" Sandy pinelands. Coastal Plain. Fla. to La. and N. C.	13778	Leaf, fruit	0.73–0.81	Mouse	37–41
Crotalaria mucronata Desv. "Crotalaria" Waste places, open woods. Sandy soil of Coastal Plain. Fla. to Ga. and Ala.	17375	Leaflet	2.44–2.63	Chick	78–84
Daubentonia punicea (Cav.) DC. "Purple-sesban" Escaping from cultivation. Fla. to La. and S. C.	13815 14651	Green seed Mature seed	1.46–1.47 0.63–0.86	Chick Chick	140–142 218–294

TABLE I (*Continued*)

Scientific and common name General ecology and distribution	Collected number[1]	Plant part fed	Equivalent % of animal body weight	Animal and weight in grams
Glottidium vesicarium (Jacq.) Harper "Bladder-pod" Moist soil and waste places. Coastal Plain. Fla. to Tex. and N. C.	Carlton	Mature seed	1.13–1.20	Chick 135–145
	13991	Green seed	1.91–2.00	Chick 162–173
	13991	Leaflet	1.94–1.96	Chick 154–158
Lupinus cumulicola Small "Sky-blue Lupine" Scrub and sandhills. Pen. of Fla.	14022	Leaf	0.83–0.89	Chick 120–127
	14022	Leaf	1.31–1.60	Chick 73–89
Lupinus diffusus Nutt. "Lupine" Pinelands and oak ridges. Coastal Plain. Fla. to Miss. and N. C.	13589	Blade	0.46–0.56	Mouse 27–33
	15577	Root	1.69–1.77	Chick 66–69
Lupinus perennis L. "Sundial Lupine" Dry, open woods, often sandy soil. Me. to Ont. and Minn., south to Ill., W. Va. and Fla.	13536	Leaf	0.46–0.56	Mouse[2] 27–33
	15854	Root	1.76–2.00	Chick 114–130
Lupinus villosus Willd. "Lady Lupine" Dry pinelands, sandy barrens. Coastal Plain. Fla. to N. C. and Miss.	15531	Root	1.74–1.90	Chick 60–66
Psoralea canescens Michx. [*Pediomelum canescens* (Michx.) Rydb.] "Psoralea" Dry pinelands and woody ridges. Coastal Plain. Central Fla. to Ala. and southeastern Va.	13629	Leaf, young fruit	0.46–0.56	Mouse 27–33
	13629	Leaf, young fruit	2.08–2.15	Chick 100–112
Psoralea subacaulis T. & G. [*Pediomelum subacaulis* (T. & G.) Rydb.] "Buck-nuts" Rocky limestone soil of Cedar Glades. Central Tenn. and Northwest Ga.	15763	Leaflet	1.64–1.86	Chick 65–74
	15763	Rootstock	2.06–2.26	Chick 66–73
	15763	Tuber	1.75–1.91	Chick 118–122
	15763	Tuber	2.06–2.32	Chick 62–70
Robinia boyntonii Ashe "Boynton Locust" Woods. Mountains of Ga., Ala., Tenn., and N. C.	13895	Leaflet	2.64–2.74	Chick 70–73
Robinia pedunculata Ashe "Locust" Woods. Blue Ridge and Piedmont Provinces. Tenn. and Ga.	13578	Flower	0.46–0.56	Mouse 27–33
	13578	Flower	2.42–2.62	Chick 74–80
	13578	Leaflet	1.79–1.91	Chick 75–80
Sesbania exaltata (Raf.) Cory Low grounds, stream banks, and fields. Coastal Plain and adjacent provinces. Fla. and Ga. to Tex., Okla., and Tenn.	14019	Leaflet	1.67–1.86	Chick 152–171
Tephrosia virginiana (L.) Pers. "Goat's Rue, Devil's Shoestring, Rabbit's Pea" Dry soil, open woods. Fla. to Tex., north to Kan., Wisc., Ont., and N. H.	13814	Leaflet	1.62–1.67	Chick 70–72

[1] Locations from which collections were made and other data for all experimental plant collections are tabulated on herbarium specimens on file in the University of Georgia Herbarium.

[2] Two similar groups of five mice each were identically treated plus three consecutive feedings at 24-hour intervals to a third group.

Astragalus michauxii (Kuntze) Hermann. An erect, perennial herb from an underground rootstock, growing to 1.2 m., at first pubescent, later becoming glabrous; leaves pinnately compound, leaflets 15–25, linear, 9–20 mm. long; flowering racemes erect; corolla white; pod 2–4 cm. long, glabrous, slightly curved upward.

Daubentonia punicea (Cav.) DC. A large shrub or small tree; leaves pinnately compound, leaflets 12–40, linear-elliptic; flowering racemes densely flowered, stout, projecting outward to downward from main stem; corolla orange; pod 6–8 cm. long, stalked, and prominently 4-winged longitudinally.

Glottidium vesicarium (Jacq.) Harper. An annual of rapid growth; stems to 4 m. tall, branching from near base upward; leaves pinnately compound, leaflets 24–52; stems and leaves with a light green appearance, flowers in small, long-peduncled clusters; corolla yellow; pods ellipsoid, acuminate at both ends, 5–8 cm. long, slightly turgid, containing two seeds.

Lupinus cumulicola Small. A perennial with evergreen leaves growing to 15 dm. tall; stem solitary from underground rootstalk, branching above; leaves petioled, simple, the blades oval or elliptic, 3–15 cm. long; flowering racemes erect, the petals blue except for a white spot at center of standard; anthers of two kinds; pod linear, turgid, 4–5 cm. long, silky, the beak curved.

Experimental Animal Observations

Astragalus michauxii. Several species of *Astragalus* have, at times, been responsible for toxic manifestations in grazing animals (9). Such plants are eaten by horses, cattle and sheep when more palatable forages are not available on the range or in the pasture. Whenever a sufficient amount of these poisonous plants is consumed, animals show clinical evidence of toxicity, including dullness, muscular weakness and incoordination, emaciation, anorexia and death. *A. michauxii* has not been listed among the toxic Astragali (9), and no reference has been found to indicate that it has been tested experimentally for such toxic properties as it may possess.

The test portion of the plant fed to the experimental chicks was leaflets, and two groups of five birds each were fed. Birds in group I (102–105 grams) each received processed leaf material in an amount equivalent to 1.65–1.67 percent of animal body weight, while those in group II (80–84 grams) each received the equivalent of 1.83–1.92 percent body weight.

There was no clinical evidence of toxicity until 12–14 hours after feeding, and in those that recovered, the symptoms reached a peak and finally terminated over periods of time up to 36 hours. Symptoms included depression, ruffled feathers, muscular weakness and incoordination, reduction in body temperature and heart rate, and anorexia. Four out of the ten birds died and, in addition to the above symptoms, exhibited lethargic-like manifestations just prior to death. Death occurred within 24–36 hours after feeding, the lethal dosage being equivalent to about 1.70 percent of body weight. Negative results were obtained when this plant material was fed at the equivalent of 0.94–1.00 percent of body weight to experimental mice (30–32 grams), thus indicating that *A. michauxii* may not be especially toxic for this animal.

Daubentonia punicea (Purple-sesban). Seeds of *D. longifolia* (*D. drummondii*) are reported (9) to cause poisoning of sheep and goats. Small quantities produce depression, diarrhea and rapid pulse in cattle, sheep and goats (7). West and Emmel (18) report poisoning of sheep, chickens and pigeons by seeds of *D. punicea*. The extent to which this report is based on research by these per-

sons is not known, their report of poisoning of chickens, for example, being based on studies by Shealy and Thomas (14) on whole seed named as *D. longifolia*. Death occurred in one to eight days. No reference in literature (11) is made to the use of *Daubentonia* as a source of medicinal agents.

Seeds of *D. punicea* were used to feed experimental chicks in two groups of five birds each. The birds in group I, weighing from 218 to 294 grams, each received the mature seed material in an amount equalling 0.63 to 0.86 percent of body weight. Birds in this second group ranged in weight from 140–142 grams and received amounts of green seed equivalent to from 1.46 to 1.47 percent of body weight. The syndrome of symptomatic toxicity was most pronounced in the birds of group II which received relatively greater amounts of seed material.

Acute toxicity was evidenced by all ten birds two hours after the experimental feedings. At that time all in group I were severely depressed; in addition to such depression, the birds in group II were found to have slightly lowered respiratory rates and slightly lowered body temperature. The next manifestations observed included a mucoidal type of diarrhea, labored respiration, anorexia and weakness, all of which continued until death. Death was immediately preceded by mild convulsions, muscular tremors and chirping sounds. All birds died, death in those of group I occurring as early as five and as late as 18 hours after feeding, while the time interval of mortality among those in group II ranged from three to nine hours.

Necropsy study very consistently revealed enteritis which was most intense in the birds receiving the relatively greater dosage of seed material. Other changes which were found inconsistently included hepatic and more or less general congestion. The somewhat diverse action noted in the result obtained seem to suggest that possibly more than one toxic factor for chickens is contained in *D. punicea* green seeds. The lethal dosage appears to be an amount equivalent to less than 0.63 percent of the body weight of the bird.

Glottidium vesicarium (Coffee Weed, Bladder Pod, Bagpod). Toxicity of this species was demonstrated in white leghorn hens by Emmel (5) who found that the smallest number of seeds required to produce fatal toxicity was 150. After feeding as few as 100 seeds to two birds, symptoms of poisoning were shown but fatal results did not follow. Seeds were low in palatability for experimental birds when they were allowed free access to them. The most consistent gross lesions in affected birds included necrotic enteritis and necrosis of the lining of the bulbous portion of the ventriculus.

West and Emmel (18) have stated that the seeds of *G. vesicarium* are also toxic for hogs, goats, sheep and cattle, causing marked depression and sluggishness as early symptoms. Affected animals later show, in addition, frequent micturition and shallow, accelerated respiration. Death is preceded by increasing depression and finally coma. They further point out that the green seeds are considerably more toxic than mature seeds. No record has been found in the literature to indicate that leaf material has been tested for toxicity.

In our Georgia studies feedings of green and mature seed material in amounts equalling 1.13–2.00 percent of body weight to chicks gave results similar to those obtained by Emmel (5) on hens. Leaflets of *G. vesicarium*, however, when fed to a group of five experimental birds weighing 154–158 grams and receiving an amount equalling 1.94–1.96 percent of body weight gave no evidence of toxicity through 36 hours of observation, and it is assumed that if the leaflets do contain a toxin, it must

be present in clinically insignificant amounts.

Lupinus cumulicola Small. Lupines, of which at least nine species are poisonous to animals, have caused serious losses at times among sheep and less frequently among cattle and horses (9). Most of these losses have occurred in western United States during seasons in which grazing animals have, due to lack of other forage, consumed seeds of the plants. Although seeds are the most poisonous portion of the plant, seed pods alone and leaves may sometimes cause poisoning. Several alkaloids have been isolated from various *Lupinus* species (11).

Muenscher (9) has emphasized that not all *Lupinus* species are poisonous. Such an opinion is well substantiated in southeastern United States where several species of *Lupinus* have long been used for forage crops with no poisoning hazard for grazing animals. Of the four *Lupinus* species examined, toxic manifestations could be demonstrated for only *L. cumulicola* Small, as below described.

Lupinus cumulicola, or Sky-blue Lupine, found in the Florida peninsula, has not previously been included among the poisonous lupines. Two groups of five chicks each received capsules containing finely ground, dried leaves of *L. cumulicola*. The birds (120–127 grams) in group I received amounts equalling 0.83 to 0.89 percent of the body weight, while those (73–89 grams) in group II were fed amounts equalling 1.31 to 1.60 percent of their body weight. Chicks in group I began to show rather mild toxic manifestations in the form of depression, increased respiration, muscular weakness, incoordination and depressed heart action, beginning about four hours after the experimental feeding. In eight to nine hours after feeding all symptoms had disappeared, and all birds in the group were apparently as normal as the control chicks. The same syndrome, though of more severe degree, began in chicks of group II during the third hour following feeding and remained well marked in all birds. Three birds were dead by the end of 48 hours after feeding. The remaining two recovered slowly and appeared to be completely normal by the end of the seventh day following feeding.

While the results indicate the presence of one or more toxic factors in the leaves of *L. cumulicola*, it is obvious that large amounts of the raw plant material must be consumed before the toxicity reaches clinical significance, at least in chickens.

Non-Toxic Species

Materials of some species in Table I produced no toxic manifestations in experimental birds and/or mice. Reference to certain of these species is made in the discussion of species showing toxicity. Pertinent data about these and the other experimental species are not yet presented.

Baptisia species have been reported as poisonous (9), but definite information concerning their poisonous properties seems largely to be lacking. It is significant that the six species in our studies demonstrated no toxic effects. One species was fed experimentally in an amount equivalent to 3.30 percent of animal body weight with negative results.

Crotalaria species are known to cause poisoning of animals. Piercy and Rusoff (13) clearly demonstrate toxic activity of *C. spectabilis* Roth. Another species, *C. sagittalis* L. has been reported by Bessey (2) to cause poisoning of horses. The two species of the present study are closely related to the latter species. Small (16) reported that *C. maritima* was utilized by the Seminole Indians to make an infusion used as a cure for sore throat. The negative results on *Crotalaria* in our tests, therefore, were unexpected. Feedings of two species to

chicks could not be made because of the limited amount of available plant material.

Some *Lupinus* species are known to be poisonous and others are not, as has been pointed out earlier. Muenscher (9) states that three species occur in the eastern United States and implies that *L. perennis* L. in that area is poisonous. Six native species of *Lupinus* are listed for the eastern United States by Small (16), four of which we studied. It is significant that only one species exhibited toxic symptoms; the other three, including the supposedly poisonous *L. perennis*, exhibited mild symptoms which might have been due to conditions in the laboratory at time of the experiment. A repeat feeding to a second group of mice gave negative results. Three consecutive group feedings of leaves at 24-hour intervals was also made to five mice with no positive results.

Two western species of *Psoralea*, native to the prairies, are listed by Muenscher (9) as being poisonous. Contrariwise the tuberous roots of two species (*P. esculenta* Pursh. and *P. cuspidata* Pursh.) have been used as food. The negative results with the two species tested in the studies here reported would seem to indicate a possible source of food in an emergency and that no toxic principle is present in them.

Robinia species have been reported to cause poisoning, bark and young shoots of *R. pseudo-acacia* L. being reported by Cary, Miller and Johnstone (3) to fatally poison horses, mules, cattle and sheep. Leaves of the same species have been reported by Barnes (1) to poison chickens. Pammel (12) reports *R. viscosa* Vent. to be poisonous. Plant parts of the two species we studied gave negative results. This suggests that a considerable difference in toxicity exists between various species of *Robinia*, especially since relatively large doses of leaf material of both species in our study produced no visible toxic effects.

The genus *Sesbania* is considered by some taxonomists to include *Daubentonia punicea* and *Glottidium vesicarium*, both of which have been shown by our present studies to be toxic. The genus also includes *Sesbania exaltata* and other species. Since this latter species is closely related to species known to be poisonous, it was a possible poisonous plant. It is consistent with previous studies that negative results were obtained with leaflets of this species and *Glottidium vesicarium*. Because of the small size of the seed of *Sesbania exaltata*, they were not collected for feeding tests.

Studies of *Tephrosia* by Sievers et al. (15) and others have shown that the wood of the root is frequently toxic (the root bark not toxic), the seed sometimes toxic, and the herbage not toxic to certain insects. The plant is poisonous also to fish but not to mammals. It seemed remotely possible that *Tephrosia* might be toxic to birds, and so available material (leaves) of one species was tested on them. Because of the probable higher concentration of the toxic substance in the roots, feedings of root material to the chickens would have given a better indication concerning any toxic relationship.

Acknowledgments

This investigation was supported in part by research grant G-3376 from the National Institutes of Health, Public Health Service. Certain equipment made available by the School of Veterinary Medicine and by the Poultry, Zoology and Botany Departments is very much appreciated. Useful advice and suggestions from a number of persons are gratefully acknowledged. We are especially indebted to Dr. Leonora Mirone, Dr. V. B. Robinson, Dr. E. P.

Odum and to our assistants, especially Ellise Erwin, James W. Hardin, Lois P. Drawdy and Frank A. Hayes, the latter being largely responsible for developing the techniques used in feeding the mice.

References

1. Barnes, M. F. Black locust poisoning of chickens. Jour. Amer. Vet. Med. Assoc. **59**: 370–373. 1921.
2. Bessey, C. E. The rattlebox, *Crotalaria sagittalis* L. Iowa Agr. Coll., Dept. Bot. Bull., pp. 111–115. 1884.
3. Cary, C. A., E. R. Miller, and G. R. Johnstone. Poisonous plants of Alabama. Ala. Polytech. Inst. Circ. 71. 1924.
4. Duncan, Wilbur H., and T. J. Jones. Poisonous plants of Georgia. Bull. Univ. Ga., 49, No. 13, 46 pp. 1949.
5. Emmel, M. W. The toxicity of *Glottidium vesicarium* (Jacq.) Harper seeds for the fowl. Jour. Am. Vet. Med. Assoc. **87**: 13–21. 1935.
6. Gowanloch, James N., and Clair A. Brown. Poisonous snakes, plants and black widow spider of Louisiana. Louisiana Dept. of Conservation, New Orleans. 1953.
7. Huffman, Ward T., and James F. Couch. Plants poisonous to livestock. U.S.D.A., Yearbook of Agr., Keeping livestock healthy. U. S. Gov't Printing Office. 1942.
8. Massey, A. B., and R. D. Hatch. Poisonous plants. Bull. Va. Poly. Inst., 36, No. 8, 52 pp. 1943.
9. Muenscher, Walter Conrad. Poisonous plants of the United States. The Macmillan Company, New York. Revised 1951.
10. Odum, Eugene P. The cardio-vibrometer: a new instrument for measuring the heart rate and other body activities of animals. Ecology **21**: 105–106. 1940.
11. Osol, Arthur, and Farrar, George E., Jr. United States Dispensatory. J. B. Lippincott Co. 1947.
12. Pammel, L. H. Manual of poisonous plants. 977 pp. Cedar Rapids, Iowa. 1911.
13. Piercy, P. L., and L. L. Rusoff. *Crotalaria spectabilis* poisoning in Louisiana livestock. Jour. Amer. Vet. Med. Assoc. **108**: 69–73. 1946.
14. Shealy, A. L., and E. F. Thomas. *Daubentonia* seed poisoning of poultry. Univ. of Fla. Agr. Exp. Sta. Bull. 196. 1928.
15. Sievers, A. F., G. A. Russell, M. S. Lowman, E. D. Fowler, C. O. Erlanson, and V. A. Little. Studies on the possibilities of Devil's Shoestring (*Tephrosia virginiana*) and other native species of *Tephrosia* as commercial sources of insecticides. U. S. Dept. Agr. Tech. Bull. No. 595. 40 pp. 1938.
16. Small, J. K. Manual of the Southeastern flora. Published by the author, N. Y. 1554 pp. 1933.
17. Smith, E. V. The poisonous plant problem in the Southeastern States. N. Amer. Vet. **24**: 345–353. 1943.
18. West, Erdman, and M. W. Emmel. Some poisonous plants in Florida. Fla. Agr. Exp. Sta., Bull. 468, 47 pp. 1950.

Utilization Abstracts

Plant Materials and Human Fertility. An article on this subject, so far as it pertains to primitive peoples, contains an alphabetic list of 60 plants, with botanical and common names, countries concerned and notes on the uses of these materials. In addition, it refers to the powerful antithrombic agent, rutin, obtained from *Ruta graveolens;* to the muscle-relaxant, tubo-curare, extracted from the Indian arrow poison of Guiana; to the heart-regulating agent, crataegolic acid, in *Crataegus oxyacantha;* to the alkaloids of *Rauwolfia serpentina* which reduce blood pressure and act as a general sedative; to the glucoside, foliandrin, from the oleander shrub, providing a cardiac stimulant of great value to elderly patients; to the coronary stimulant, khellin, obtained from *Ammi visnaga;* and to the antimalarial, febrifugine, isolated from *Hydrangea* and very recently synthesized. (M. De Laszlo & P. S. Henshaw, *Science 119: 626. 1955*).

Introducing Black Pepper into America

Because of the decline of pepper culture in southern Asia and its resulting scarcity, the Section of Plant Introduction of the United States Department of Agriculture has recently procured ten varieties from the Malabar Coast of India for introduction into tropical America. Pepper culture in India is an ancient gardening handicraft. The vine shows considerable genetic variability, making it a pliable prospect for adaptation to new cultural methods in the New World.

HOWARD SCOTT GENTRY [1]

History

Black pepper (*Piper nigrum* L.) is the commonest spice on the American table, where it is so familiar that we scarcely pause to consider it as an exotic. Yet it still comes to us from the other side of the world, and the plant is stranger to us than coffee or vanilla. Out of the Old East it is one of the fabulous spices that baited the ancients to venture on the Indian Sea and enticed Columbus to our nameless shores. In Roman times it was an important article of trade between Europe and Asia, and upon occasion was employed as money. It appears to have originated as a cultivate out of the wild plants which are still found growing upon the slopes of the Malabar Coast in southwestern India. Here its cultivation is known to be historically old, as it is referred to in ancient Sanskrit writings. Judged by modern geographic criteria, it may have been among the first hundred or so of the world's cultigens. Sauer (10) is inclined to accept southern Asia as probably the first main source for the beginnings of plant culture.

Man in maritime woodland with an assured subsistence of sea food could have had the necessary security and leisure to attend the coincidental culture of roots and cuttings of the plant foods he gathered to his shelter from the surrounding forest. Sauer indicates perennials, rather than annuals, as the first cultivates, since by sectioning off a selected wild variety, it was immediately perpetuated for use. In this way are avoided the frustrations inherent in genetic mischance, as may result with planting seeds. The latter also require more care and time until they reach maturity. Among the ancient cultivates which have always been cultivated vegetatively, and which are native to the Malabar Coast, are the bananas (*Musa* spp.), some of the edible palms, cardamom (*Elettaria cardamomum*), yams (*Dioscorea* spp.) and sugarcane. In this group also is black pepper. Since it as a cultigen fits so snugly into what is regarded as an incipient agricultural pattern and in a wooded maritime Asian area (Fig. 1), it may be very ancient; just how many thousands of years we shall never know.

From the Malabar Coast, black pepper culture appears to have moved eastward to the Malay Peninsula and adjacent islands by the seventeenth century. Marco Polo (8) recounts its cultivation on Java during his visit there in 1280 A.D. Its exploitation appears to have been greatly increased in Indonesia under Chinese and other colonial interests until World War II. By 1939 Indonesia was

[1] Section of Plant Introduction, Horticultural Crops Research Branch, Agricultural Research Service, United States Department of Agriculture, Plant Industry Station, Beltsville, Maryland.

producing the bulk of the world's pepper, 133 million pounds, far-passing India's production of 34 million pounds in the same year. Pepper is now cultivated in and exported from Nigeria also. Presumably it was introduced there by the Portuguese during their virtual monopoly of the trade from 1498, when the sea route around the Cape of Good Hope was discovered, until the eighteenth century. The French appear to have been the first to introduce black pepper to the Americas (1). During the middle of the 18th century it was started near Cayenne in French Guiana and was apparently a successful crop with the slave labor then employed. When slave labor was abolished in the 19th century, its cultivation deteriorated. However, French introductions on Guadeloupe Island in the Lesser Antilles were still in existence in 1942. Plants now firmly established at the Federal Experiment Station at Mayaguez, Puerto Rico, are reported to have come from that source.

Commercial black pepper introduction is reported to have been effected in the Americas in recent times by Japanese settlers near Belém in Brazil, where annual production is now about 160,000 kgs. This is all consumed within that country. The plant has appeared occasionally in gardens and greenhouses of the United States. Bailey (2) reports it as hardy in Santa Barbara, California. The first record of it as a United States Department of Agriculture introduction is as a packet of seed (P.I. 5167 [2]) sent from Bangkok, Siam, by Lathrop and Fairchild in 1900. There is no record of the survival of these seeds. Since 1900 the Section of Plant Introduction has brought in black pepper from time to time, and records of these introductions

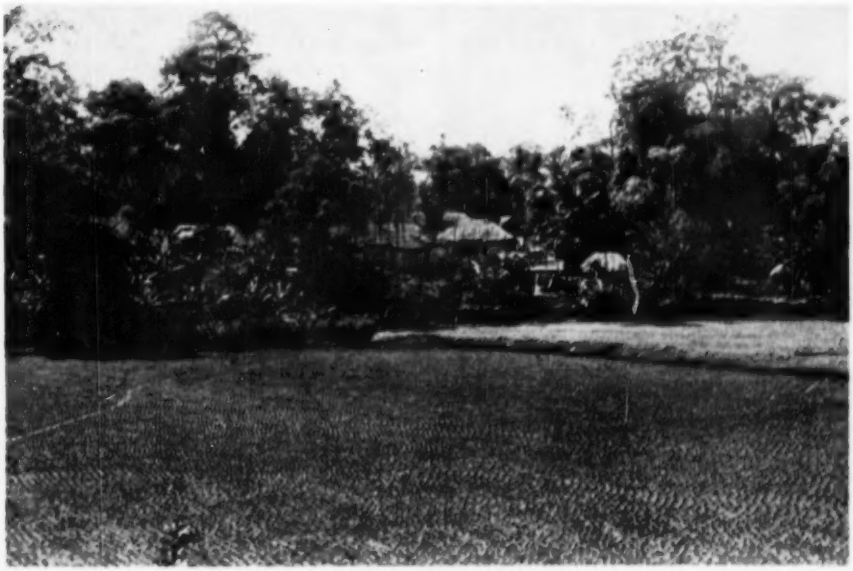

FIG. 1. The habitat of black pepper along the Malabar Coast. Rice padi in the foreground with a wooded village showing plantings of banana and areca nut palm.

[2] P.I. refers to accession number of the Section of Plant Introduction.

may be found in the printed inventories of the Section. Most earlier introductions were in the form of seed, since the much more valuable clonal material, prior to the air age, could not survive the long ocean trip from the Old World tropics. As recently as 1950 the Section obtained seed of black pepper from Indonesia, one introduction (P.I. 193021) from the island of Bangka and another (P.I. 193022) from Sumatra. Seedlings of these introductions were grown at the Federal Plant Introduction Garden, Glenn Dale, Maryland, and later distributed to test localities in this hemisphere.

Air transport and the availability of plastic wrapping for shipping vegetative cuttings have made it possible to bring in the best clonal lines of black pepper.

The first successful introduction of clones of commercial varieties of black pepper into the United States was made early in 1953. These were obtained from the Pepper Experiment Station near Taliperamba on the Malabar Coast of southwestern India by a private collector. Because of quarantine regulations this material was turned over to the Section of Plant Introduction for propagation and increase. They represented the varieties Balamcotta (P.I. 205364) and Kalluvalli (P.I. 205365), and consisted of 199 cuttings. Twenty-nine of these, representing the two varieties, were successfully established at Glenn Dale. Following increase propagation this material was sent to Mayaguez, Puerto Rico, for trial, further multiplication and distribution.

According to Watt (13), imports of black pepper into the United States in

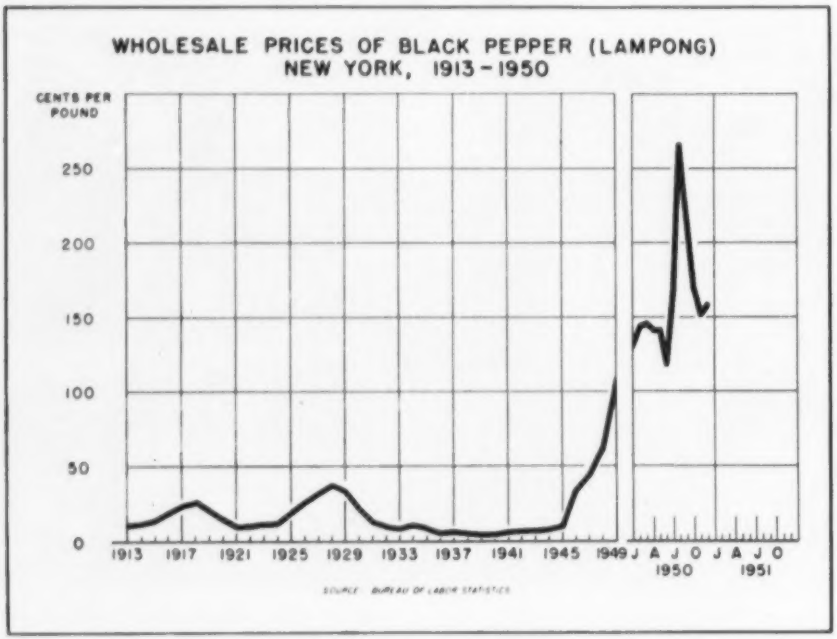

FIG. 2. Graph showing wholesale prices of black pepper (Lampong). New York, 1913–1950.

the 1880's ranged between 15,000 and 65,000 pounds per annum. By the late 1930's our annual imports were averaging over 50 million pounds a year (11). Shortly after that the war cut off supply, and a ceiling price of 15 cents a pound was set by the Office of Price Administration. Black pepper became scarce or lacking on many American tables. There were also complaints from the servicemen who failed to find the accustomed incentive to nourishment on the mess table, and it was considered as a morale factor by the armed services. Because of the deterioration of the pepper gardens in Indonesia during the war and the lack of a dependable market, world exports dropped from about 170 million pounds in 1939 to 50 million in 1949. After the O.P.A. price ceiling was lifted, the price of pepper reached spectacular heights, the spot-price going to $2.65 per pound in 1950 (Fig. 2). Since then it lowered to about $1.15 per pound in 1953, and to 80–85 cents per pound in 1954 (12). Present conditions in Asia do not favor any large increase in pepper production in the near future.

Because of these conditions and the favorable prospect of pepper as a crop for tropical America, the Department of Agriculture has become interested in securing good propagation stock of established commercial value. In India it is probably most profitable as an intercrop with coffee, which incidentally is an indicator of its environmental requirements. However, through the lower elevations along the Malabar Coast, it is an important cottage industry. Cultivated as a garden plant in small plots from a fraction of an acre up to several acres, it provides the individual farmer with a basic cash source. In this way it would seem to fit well also into the pattern of the small-plot maize planters and gardeners of Latin America.

Accordingly the author, as plant explorer for the Section of Plant Introduction, was instructed to procure clonal materials of desirable black pepper varieties at the convenience of the Section's 1953–54 Asian Expedition for forage crop germplasm. The following is an account of the introductions of black pepper obtained and observations on pepper culture, as well as a discussion of some of pepper's interesting features and possibilities in the Americas.

FIG. 3. Mature vine of black pepper on old forest tree in coffee plantation in Coorg.

Botanical Description and Habitat

Piper nigrum is a perennial, drought-deciduous, polypodial vine with alternate, shiny green, ovate, thickish leaves. Shoots develop perennially as runners

with adventitious fastener roots clinging to tree trunks. Basal shoots also occur near the base of the plant and may strike root to form new plants. Lateral or "hanging" branches form in time a rather dense cylindrical canopy of foliage (Fig. 3). The inflorescence is borne terminally, as spikes two to eight inches long, on these secondary and tertiary branchlets (Fig. 4). The flowers are small, apetalous, perfect or imperfect, and subtended by a small scale-like bract on a thick rhachis. Some varieties appear to be completely dioecious, as the Uthirancotta and wild forms; others may be wholly perfect, as variety Kalluvalli, or partly perfect, as variety Balamcotta. The presence of stamens on pistillate plants has been regarded as necessary to good yields (7, 9), but the author's observations question this (6). The vines climb upon trees to heights of 30 or more feet and may live as long as 100 years, although production is reported to decrease after vines have reached 25 to 30 years of age. A good account of the cultivated Indian varieties is given by Menon (9).

FIG. 4. Balamcotta variety of black pepper with partly filled fruiting spikes growing on a dead tree in Coorg coffee estate.

The habitat of wild pepper as observed on the Malabar Coast is the wooded maritime slopes of the Western Ghats between 8 and 16 degrees north latitude, and at elevations between 500 and 8000 feet above sea level. The annual average rainfall in this area ranges, according to locality, between 60 and 150

inches. About 80% of this falls in the monsoon months from May 1 to October 30 in the southern or Travancore part of this area, and from June 1 to September 30 in the northern part of the area. The winter-spring dry spell northward is accordingly much more severe than in Travancore. The temperatures are generally tropical-equable, but commonly range annually between extremes of 50 and 104 degrees F. Relative humidity varies greatly between seasons, and between near coastal areas and more inland ones at higher elevations. A wild vine of *Piper nigrum* was observed in good fruiting condition at 8000 feet elevation in the Nilgiris Mountains of southern India, where frosts are reported of annual occurrence during winter months. Certainly, however, most of the area of both wild and cultivated black pepper is in frostless climate. All the wild vines observed were found on forested slopes, growing in the shade of trees, upon which they were climbing, among rocks in coarse well-drained soils covered with a light natural mulch of forest litter. Cultivated plantings were noted from near sea level to 4000 feet elevation, all rainfed with annual average rainfalls varying from 40 inches in eastern Coorg to 140 inches in Talipe-ramba.

The Malabar Introductions

A total of 20 lots of live cuttings and nine lots of seeds was collected along the Malabar Coast and adjacent area in the States of Coorg, western Madras and Travancore-Cochin. Of these, only 11 collections of cuttings and four of seeds survived. Mortality in the cuttings was primarily due to delays in over-seas air shipments and to placing too many cuttings in the pliofilm bag. The stems are rather succulent, and moisture accumulating by transpiration will in a few days cause cuttings to mold and rot. Eight or ten cuttings in a 4- × 11-inch bag will carry much better than 50 cuttings in an

FIG. 5. Balamcotta (left) and Kalluvalli (right), the two standard black pepper varieties of Coorg.

8- × 16-inch bag. Our best survivals came from basal shoots and from the smaller lots of less tender material. The tips of terminal shoots do not carry. Transport time from cutting to planting should not exceed eight days. Although not tried, an absorbent material such as dry moss inserted in the bag with cuttings might prevent accumulation of excess moisture. Pliofilm bags are excellent for carrying live plant materials, but in such cases as this their moisture-holding capacity may work to excess. The seed lots from ripe fruits collected in March gave very good germination, 80 to 90%, while seeds of immature fruits collected in January did not germinate.

An annotated list of the varieties collected follows. Foliage characters of the two most important of these are shown in Fig. 5, representing plants growing in the plant introduction greenhouses at Glenn Dale, Maryland.

BALAMCOTTA (Coorg[3]) P.I. 213299. Vigorous vines with dark-green foliage, characterized by long partly filled fruiting spikes and large broadly ovate primary leaves of the branchlets, the occasional large leaves thus appearing among the more numerous smaller ones. The spikes are four to six inches long with some of the flowers showing one or two stamens. Usually close inspection reveals at least a few stamens towards the base of the spike, frequently only one to a pistil. The spikes are almost never filled and support numerous small ovules which fail to develop. Balamcotta is reported to yield heavily in some years, and at such times its yield exceeds that of Kalluvalli, the other standard variety of Coorg. Cultivated at 3000- to 4000-feet elevations with 40–70 inches of annual rainfall on slopes, with coffee.

BALAMCOTTA KUDRAVALLI (Travancore) P.I. 212965. Vigorous vines with heavy dark-green foliage; spikes five to seven inches long, well-filled or loosely filled, with perfect flowers. This variety is like Balamcotta of Coorg, but the vines appeared more vigorous and the spikes generally longer. It may be that some flowers along the rhachis lack stamens, as in Coorg. Cultivated from 500- to 700-feet elevations with 100 to 150 inches of rainfall on sloping lateritic soils.

KALL-BALAMCOTTA (Coorg) P.I. 213294. So-called because it combines certain characters of the two varieties Kalluvalli and Balamcotta, having the leaves, the perfect flowers and the closely set fruit of the former, with the spikes tending to elongate like those of the latter. The spikes appear to be produced in more than average number, placing this variety among the most heavy yielders observed. Corn size and pungency are also good. It is relatively rare, but several vines exist on both Wusholly and Balmane estates of the Pollibetta group. The management of these estates is using material of this variety as propagation stock for expansion and replants, considering it their best yielder on the basis of two-year records of individual plants. Cultivated with coffee on sloping lateritic soils with 40–70 inches of annual rainfall from 3000- to 4000-feet elevations.

KALLUVALLI (Cannanore) P.I. 213291. Vigorous vines eight to 12 years old with large green leaves, mostly perfect flowers; spikes about three inches long with densely set fruits. A good yielder, but spikes perhaps not so abundant as on the Travancore Kalluvalli type, "Veluthanabum". Cuttings were taken from basal shoots which had been either tied up along the support or coiled and hung on forked pegs. Cultivated near sea level with 125–150 inches of rainfall on loamy lateritic slope soil.

KALLUVALLI (Coorg) P.I. 213296. Large climbing vines with rather sparse or open

[3] Names in parentheses represent the state or district from which the introductions come.

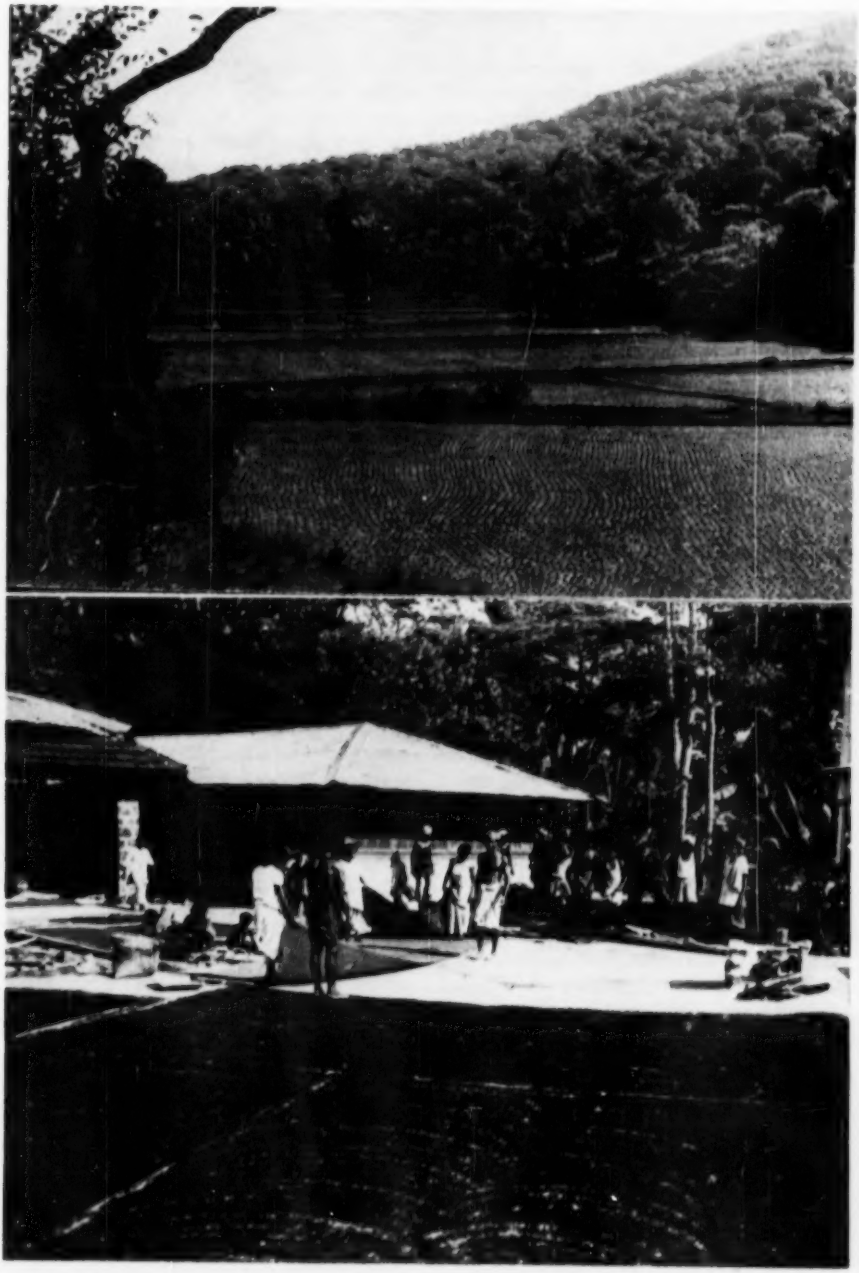

Fig. 6 (*Upper*). A typical view in the highland State of Coorg. Padi in the bottomland with coffee and black pepper on the forested slope in the background.

Fig. 7 (*Lower*). Drying black pepper (foreground) and tramping off the corns from freshly picked spikes (background). Perumila Tea Estates, Travancore.

foliage of medium-sized, rather regularly ovate leaves, evenly distributed short spikes with perfect flowers and densely set fruits; spikes 2½ to 3½ inches long. Kalluvalli has been the standard of reliable yielders in Coorg, and the general similarity of vines through the coffee plantations suggests that all originally came from the same clonal stock. Many of the vines are 30 or more years old. Extension of planting and replacement of failing or damaged plants are now in many cases being done with better yielding strains, such as Kall-balamcotta and Karincotta, or Kalluvalli types from other areas. One of the latter was secured and is in propagation at Glenn Dale (P.I. 213292).

There are few pure gardens of black pepper in Coorg. Pepper is inter-planted with coffee, shade trees being used as supports. Many of the latter are remnants of the forest which originally covered these slopes; they consist of *Ficus* spp., rosewood or *Dalbergia latifolia*, and of planted ones, such as *Grevillea robusta*, *Terminalia tomentosa* and *Albizzia odoratissima*. These plantations all occupy the slope lands, while rice is planted in the moist inter-bottomlands (Fig. 6). Elevations range from about 3000 to 4500 feet above sea level, and annual rainfall grades from about 70 inches on the west to about 40 inches on the east, approaching the drier Bamboo Deciduous Forest, in which pepper is not found either wild or cultivated.

KARINCOTTA, KARINGOTA (Coorg) P.I. 213293. Cuttings from basal runners being propagated in a nursery were obtained. The variety was stated by the owner to be one of the two best varieties he had been able to locate in a private survey of Indian black pepper varieties. Menon (9) says of this variety, "This is cultivated in the Wynaad taluk of Malabar and is mostly found in the neighborhood of Manantoddy. This is a promising variety which exhibits regular bearing and yields well. Moreover it is not easily affected by unfavourable seasonal conditions as the other varieties. It is a hardy variety living up to forty years. The leaves are very tough, dark green in colour and project out horizontally and measure 16.4 × 9.5 cm. The spikes measure 7.0 to 11.5 cm. Though short, they are well packed with medium-sized berries. When fully grown, the spikes become twisted in their axis and curved".

KOTTANADAN, KUDARAVALLI (Konni) P. I. 212962. This is a robust climbing vine characterized by twisted spikes and absence of stamens. Some of the inflorescences are compounded by branching. Kottanadan forms a large mass of foliage of medium-sized ovate leaves. The single or compound spikes are three to four inches long, and were well-filled, packed in fact, when observed in January. Although spikes did not appear so numerous as in some other varieties, Kottanadan is considered to be a good yielder. As a genetic source it should prove very valuable. As observed near Konni the variety occupied elevations of 500 to 800 feet with an annual rainfall between 100 and 150 inches.

This variety is of particular interest, since it is a conspicuous exception to the general impression that perfect flowers insure good yield; unisexual flowers, poor yield. Although without stamens, the spikes are as well-filled as any of the perfect-flowered forms examined. This point is discussed in a separate paper (6).

UTHIRANCOTTA (Coorg) P.I. 213297. Only pistillate plants of this dioecious variety were observed. It is a hardy vigorous vine with dark green foliage. Yield is irregular and light; infrequently cultivated. Primarily of genetic interest.

VELUTHANABUM or KALLUVALLI type (Melankara) P.I. 212964. Large climbing vine with sparse open foliage of uniform ovate leaves like typical Kalluvalli, but the spikes are longer, four to

five or even six inches, and well-filled, with stamens present. The people of the Melankara Rubber Estate near Todapuza, Travancore, considered it their best yielder, mature vines yielding up to 15 pounds of dry pepper in good seasons. Cultivated at Melankara Rubber Estates at about 600-feet elevation with 100 to 150 inches of annual rainfall.

WILD PLANTS. Cuttings were collected from vines growing in rather humid forest on rocky slopes of the Western Ghats near the western boundary of Coorg, above Tellicherry, at about 1000 feet elevations. Polypodial vines with rather small, regular, ovate, dark-green leaves, all of which were without inflorescences (P.I. 213290).

Another lot was collected near the top of Dodo Betta Mountain above Ootacamund in the Nilgiris at about 8000 feet elevation. "Wild vine climbing on Ilex tree; dioecious; spikes 4–5 inches long, well-filled with corns, but scarcely pungent". Both seedlings and cuttings from this vine have been established at Glenn Dale (P.I. 214300). Rainfall was reported to be about 40 inches annually at this locality, and light winter frosts are of regular occurrence. My Indian companion stated that, were this vine transplanted to the warm lowlands, it would produce pungent corns.

General Observations on Indian Pepper Culture

Pepper cultivation in India follows traditional lines. Culture is by hand, either wholly or largely as an indigenous gardening method. Through the Malabar coast lowlands a large acreage is collectively formed by small individual gardens cultivated by the resident families, usually in conjunction with *Areca* nut palms and coconut trees which serve as supports for the vines. I observed no artificial standards in use, although the betel leaf (*Piper betle*) is so grown. The larger plantings may consist of ten or 20 acres, as cleared from jungle or taken from other crop lands with standing or planted trees used as supports.

It is also planted as a secondary intercrop with coffee and tea in the middle elevations of 2000 to 4000 feet in the Western Ghats. In some of these larger and better managed plantations pepper culture has recently been given more modern professional attention, such as use of the better varieties, pruning, individual record yields and fertilizing. This attention is mainly stimulated by the higher market price of pepper during the last several years, following the collapse of Indonesia exports. At present it is a highly profitable crop to the grower except in those rather many cases where middle men are able to buy at the disadvantage of the grower.

The Indian pepper gardeners have accumulated a great deal of cultural information about their fabulous specialty. Some peculiarities of the plant are of established credence and appear noteworthy here. There are basically three types of cuttings from which propagations may be made: terminal shoots, basal shoots, lateral branches. Only the first two are normally employed.

Cuttings from lateral branches were reported by the pepper specialist of the Pepper Experimental Station at Taliperamba to produce non-climbing bush types. He considered the bush variety of Perumila to be such a plant (Fig. 8). Except for its bush habit, it resembles the Cheriacodi variety, a small, short-running vine, now little cultivated because of relatively low yield and small corns.

Terminal shoots were reported to be more difficult to establish and to produce shorter-lived plants, 30 to 40 years, than basal shoots. However, they start to yield commercially in the third year, or about two years earlier than basal-shoot plants. Also, plants grown from terminal shoots do not produce basal shoots.

This report appeared to be confirmed when I was seeking basal shoot cuttings on the Pollibetta estates. Their practice has been to top vines at 25 to 30 feet for picking convenience, using the terminal cuttings for propagation. I found basal shoots rare or lacking on these estates.

Basal shoots were reported to be more easily propagated and to produce longer-lived plants than terminal shoots. They begin to yield appreciably in their fifth year and will continue to yield under good conditions for 40 years or more.

Cuttings may be planted directly in the "field" if covered with some shade, such as palm leaves or brush. The better practice is to root the runners in shaded nurseries, laying the horizontal runners over baskets or pots of soil, in which they strike root for later segmentation and moving out to the planting site in the field. Fuller information on black pepper culture is available in Menon's excellent report (9).

The harvest of pepper on the Malabar Coast is a work of hand and patience. The corns are picked green just before they ripen, as that is when pepper has its best pungency. This stage may be determined by the reddish or yellowish color appearing in the earliest vines of a planting. The point may also be determined by cutting across the end of a berry with a knife to expose the tip of the seed. When the cut shows a brownish color in the previously whitish seed, picking may begin.

The entire spikes are removed by hand into the picker's basket. Since most of the spikes are out of standing reach, the pickers work on single pole bamboo ladders, notched for steps. At the end

FIG. 8. The Perumila bush variety of black pepper. Note the short but well-filled spikes borne over the broad low crown.

of the day's work the pickings are carried to the drying yard and heaped upon an edge of the drying flat (Fig. 7). The still fresh corns are then trod upon with bare feet to remove them from the rhachises, which are then separated by hand. If the spikes are allowed to wilt or dry, the separation becomes difficult, as the berries become persistent.

The berries are next spread to dry on the drying flats. On the coffee plantations the cement coffee-drying yards are used. The individual Malabar pepper gardener usually provides a flat space which is surfaced with a firm coating of dried mud and cow dung or straw. Drying is facilitated by stirring or turning the berries daily, and, since harvest occurs during the dry season, there is usually little trouble from rain. Within two or three days the green berries turn black. With several days of additional drying in the clear sun, the crop is ready for sacking and market.

To produce white pepper it is reported (7) that the berries are allowed to ripen, and the outer hull and pulp are removed by boiling or fermentation in water with subsequent maceration. As the pungency of ripe berries is less than that of submature green ones, white pepper has a milder flavor. White pepper is apparently not produced on the Malabar Coast, and no observation of the process was made. The pungency of pepper is contributed by a resin and additional flavor by a volatile oil in the amount of 1.2–2.2%. It also contains piperine, a yellow crystalline alkaloid, to the extent of 2–8%, which has the same empirical formula as morphine, $C_{17}H_{19}NO_3$ (4).

In appraising black pepper as a potential crop for the Americas, I noted a number of things which might be done with the plant, or considered for scientific investigation:

The breeding of special varieties or strains to occupy particular environments or to meet modern cultural methods. As far as known from publications reviewed and observations, the only practice resembling breeding work has been the selection of varieties out of locally appearing variants of the species, as volunteers from dropped seeds. No term records of individual plants or lineages as regards yields and other features have been kept. Both wild and cultivated plants show a high degree of variability, as one would expect in polyploid populations. Chromosome number has been reported as $2n = 128$, and should be compared with $n = 16$ and $n = 32$ reported for *Piper betel* v. *hispidula* and *P. betel*, respectively, as well as $n = 12$ for *P. subpeltatum* (3, 5). The fact that a few fortuitous selections have perpetuated varieties which yield many fold more than others is an indication of what may be done were modern genetics applied.

Since longer than the written record, propagation has been by vegetative cuttings as the quickest and most economical way of getting a known variety into production. Propagation from seed, with subsequent records of the variants over a period of many years, has not been within the means of this cottage industry, but appears to be one of the most obvious first steps in making genetic judgments regarding the potentialities of the vine. The lots of seedlings in propagation at Glenn Dale are therefore of primary interest (P.I. 212963, 213301, 214301, 214300).

Yield is reported to be highly variable from one season to the next, it being common observation or opinion that a heavy yield is followed by a light one. Whether caused by genetic or physical factors, this is an important problem for the geneticist and plant physiologist.

Nothing has been done to develop the plant for mechanized culture. Being Asian and beyond the area of combustible power, pepper culture has remained an ancient handicraft. In moving the culture to the Americas, where mechanization is being increasingly employed, this tangent should be considered. The

Perumila bush variety of Travancore suggests that a spreading variety may be genetically or simply culturally feasible as a mechanized crop, both in cultivation and in harvest (Fig. 8). The low spreading habit, developing a bush four to six feet in diameter and two to three feet tall, indicates suitability to bedded row culture. The erect fruiting branchlets borne over the crown of the bush appear susceptible to machine mowing. This apparently would not harm the plant, since under the Perumila climatic conditions of dry winter and spring, the bushlets dry back and shed the terminal nodes by abscission after fruit maturation. While the vine habit offers little hope for employing machine efficiency, the bush habit does.

There apparently has been no serious attempt to introduce black pepper into climates that are not similar to that of the Malabar Coast where it was first cultivated. We therefore have little basis for assuming that black pepper will grow only in such a climate. It has always been a rain-fed crop. Would it not, in some of its many varietal forms, also grow under irrigation in more arid climates? Rain splatter is considered as one of the principal aids in pollination or fruit set and yield. This suggests that overhead sprinkling could be applied at the most propitious time and in the best way to insure full sets of fruits. Rainfall minimum for black pepper has generally been cited as about 80 inches per annum, but I observed mature vines yielding well on Balmane Estate of eastern Coorg with but 40 inches of rainfall, most of which is limited to the summer months. It is therefore capable of sustaining drought for several months. Additional climatic adaptability is indicated in its occurrence from sea level to 8000 feet elevation in a wild form growing on Dodo Betta Mountain in the Nilgeris, where light winter frosts occur.

In summary it appears that with the current introductions of black pepper, plantsmen are being provided with a subject to try their skills. As a cultivate it may be very old and presents a case of arrested development. Although its genetic endowments do not appear of the magnitude of corn or wheat, it shows potentialities that would carry it beyond its past opportunities. Having remained in the conservative hands of an old gardening culture, it has yet to meet the tests that beset the wayfarer in new environments. Given intelligent guidance it may find a new place in a competitive world, and this should be provided by researchers as well as farmers, as in the Americas almost everything is yet to be done with the subject.

Literature Cited

1. Anonymous (Galard de Terraube, etc.). Tableau de Cayenne oú de la Guiane francaise, etc. Paris, Chez veuve Tilliard et fils, An VII (1799).
2. Bailey, L. H. Standard cyclopedia of horticulture. Vol. 3: 2646. 1925.
3. Darlington, C. D., and Janaki Ammal, E. K. Chromosome atlas of cultivated plants. p. 66. 1945.
4. Encyclopaedia Britannica. Vol. 21: 127. 1911.
5. Gaiser, L. O. Chromosome numbers in angiosperms. II. Bibl. Gen. 6: 172. 1930.
6. Gentry, H. S. Apomixis in black pepper and jojoba? Jour. Hered. [In press].
7. Greene, Laurenz. Abstracts of some articles pertaining to the cultivation of black pepper. U. S. Dept. Agr., Off. For. Agr. Rel., Tech. Col. Branch. 1951.
8. Konroff, Manuel. Travels of Marco Polo. [p. 272]. 1926 or 1930.
9. Menon, K. Krishna. Survey of pollu and root diseases of pepper. Indian Jour. Agr. Sci. 19: 89–136. 1949.
10. Sauer, Carl. Agricultural origins and dispersals. Am. Geog. Soc. 1952.
11. U. S. Dept. Agr., Agr. Stat. 1940.
12. U. S. Dept. Comm., Census Rep. No. FT 110, Calendar Year 1953: 36, and April 1954: 15.
13. Watt, George. Dictionary of the economic products of India. Vol. 6: 267. 1892.

Reducing Capacity, Potentials and Water of Apples

RAY L. SHIRLEY [1] AND CHARLES E. BLAKE
Shepherd College, Shepherdstown, West Virginia

Abstract

Apples of the York Imperial, Rome Beauty, Red Delicious and Golden Delicious varieties have been evaluated for their capacity to reduce the ceric ion and oxidation-reduction potentials, during growth and storage, and true water content during storage, at approximately biweekly intervals. Three periods of change occurred in reducing capacity throughout growth and storage. No direct relation was obtained between the ceric ion reducing capacity of the apples and the concentration of reducing sugars present. The difference in potentials between the growing and storage periods was significant at the 0.05 level; such evaluations should be a measure of the oxidative state of the fruit. True water evaluations by toluene distillation and water traps were shown to be significantly lower than those obtained by oven drying.

Introduction

Progress in the development of a fruit depends on a better understanding of the physical and chemical properties of the product, as well as of the relation of cultural practices to yield and quality. The object of the present study of apples was to determine their (*a*) capacity to reduce tetravalent cerium, (*b*) oxidation-reduction potentials and (*c*) water content, as evaluated by toluene distillation and receiving tubes. Approximately biweekly determinations were made of the capacity to reduce the tetravalent cerium from late June until the following May; the potentials from August until the following April, and the water from January until May. As far as the literature reveals, such evaluations of apples have not previously been made. Blake and Shirley (2) reported values for the reducing capacity and potentials of peaches.

Material and Methods

Apples were obtained from 15-year-old individual vigorous trees of York Imperial, Rome Beauty, Red Delicious and Golden Delicious varieties grown on limestone soil (Hagerstown silt loam) at the West Virginia University Horticultural Farm in the Shenandoah Valley. Approximately biweekly analyses were made for capacity to reduce the ceric ion, potentials and water content during growth and storage, 1952–53. All trees were in grass sod and had received recommended spray and cultural practices. Average size apples were obtained and kept at 33° F. until analyzed; during growth, analyses were usually made within one to three days after picking. The Red Delicious and Golden Delicious were picked and put in storage on October 3, while the York Imperial and Rome Beauty were picked and placed in storage on October 28. Two or three apples of each variety were analyzed at each interval; the skin was discarded, and wedge-shaped fleshy samples from outside to core were taken.

The capacity of the apples to reduce the ceric ion and oxidation-reduction potentials were evaluated by the same procedures as used by Blake and Shirley

[1] Present address: University of Florida, Gainesville, Florida.

TABLE I

REDUCING CAPACITY, POTENTIAL AND WATER OF APPLES

Analysis	Period of analyses	No. analyses during period	Variety			
			York Imperial	Rome Beauty	Red Delicious	Golden Delicious
Reducing[1] capacity (m.eq. ceric ion reduced/5.0 gm. wet wt.)	June 24 to harvest	9[2]	4.77 ± 0.60	4.74 ± 0.72	4.30 ± 0.59	5.12 ± 0.68
	Harvest to Dec. 11	5[3]	3.97 ± 0.56	3.91 ± 0.28	3.76 ± 0.28	4.09 ± 0.49
	Jan. 8–May 1	5[4]	3.03 ± 0.21	3.33 ± 0.28	3.42 ± 0.17	2.91 ± 0.21
Potential[1] (plus millivolts)	Aug. 7 to harvest	6	382 ± 18	369 ± 19	381 ± 12	367 ± 29
	Nov. 1 to April 2	10	356 ± 40	350 ± 45	351 ± 37	349 ± 39
% Water[1,5]	Jan. 8 to May 1	9	84.8 ± 1.2	85.3 ± 1.1	85.9 ± 1.2	82.3 ± 1.1

[1] The values reported are the means of the biweekly determinations made during each period, and the standard deviations.
[2] Only 8 analyses were made on the Red Delicious and Golden Delicious.
[3] Only 4 analyses were made on the York Imperial and Rome Beauty.
[4] Analyses were made at approximately four-week intervals during this period, compared with two-week intervals during the other two periods.
[5] Determinations were made using toluene distillation and water receiving tubes.

(2) on peaches. Water determinations were made during storage on 25-gm. samples, using toluene distillation and Stark and Dean receiving tubes (1).

Results and Discussion

The data are presented in Table I that were obtained for (*a*) capacity of the apples to reduce tetravalent cerium expressed as m.eq. (milliequivalents) per 5.0 gm. of wet weight, (*b*) oxidation-reduction potential expressed as plus m.v. (millivolts), and (*c*) percentage of water as determined by toluene distillation and receiving tubes. In Table II a summary of the analysis of variance is given; the calculations were made according to the recommendations of Snedecor (3).

Oxidizing Values. As shown in Table I, the reducing capacity of the apples was greatest during growth (June 24 to harvest), intermediate during early storage (harvest to December 11) and least during late storage (January 8 to May 1). The means of the m.eq. of reducing capacity per 5.0 gm. of wet weight varied between the four varieties from 4.30 to 5.12 during growth, to 3.76 to 4.09 during early storage, to 2.91 to 3.42 during late storage. Golden Delicious had the greatest reducing capacity during growth and

TABLE II

SUMMARY OF ANALYSIS OF VARIANCE[1]

Source	Reducing capacity		Potentials		Source	Water	
	d.f.	m.s.	d.f.	m.s.		d.f.	m.s.
Subclasses	11	3.21 **	7	1334.0	Total	35	...
Variety	3	0.35	3	350.0	Variety	3	22.0 **
Period	2	15.58 **	1	7923.0 *	Within	32	1.7
Interaction ...	6	0.52	3	122.0			
Within	56	0.26	56	1227.0			

[1] Calculations were made according to Snedecor's recommendations. A single asterisk indicates significance at the 0.05 level and the double asterisk indicates significance at the 0.01 level.

least during late storage. The higher standard deviations of the values obtained during the growing season are largely due to a steady decrease in values as the apples matured. During early storage the reducing values tended to level off, but during January values were obtained at a markedly lower level. Thus three periods of change occurred in reducing capacity throughout growth and storage. During the early storage and late storage periods corresponding determinations for reducing capacity were made on apples from 30-year-old trees in the case of the York Imperial, Rome Beauty and Red Delicious varieties. Four biweekly evaluations in early storage and five monthly evaluations during late storage on each of these varieties gave means and standard deviations of 3.83 ± 0.40 and 2.98 ± 0.23 m.eq. of reducing capacity per 5.0 gm. of wet weight, respectively. The individual values showed no significant differences as a result of variety or age of the trees, but differences attributable to the two periods of storage were highly significant at the 0.01 level, which was equivalent to that shown in Table II for the apples grown on the 15-year-old trees. Blake and Shirley (2) observed a marked decrease in reducing capacity of peaches grown on sandstone soil as they approach maturity.

To determine whether there was a direct relation of the capacity of the apples to reduce the tetravalent cerium to reducing sugars, three determinations (1) of the latter were made at monthly intervals during storage in February, March and April. The means and standard deviations, calculated as percentage of fructose, for the York Imperial, Rome Beauty, Red Delicious and Golden Delicious were 6.8 ± 0.80, 5.6 ± 0.5, 8.2 ± 0.8, and 8.3 ± 0.5, respectively. Reducing sugars will react readily with the ceric ion under the conditions of this study. It is not understood why the higher values for reducing sugars obtained with the two Delicious varieties are not reflected in the capacity to reduce the tetravalent cerium. Other substances must be present in the apple to dominate the reducing capacity in the acid medium of the ceric ion reduction.

As indicated in Table II, there was no significant variation between varieties or interaction influences, but the variation of the reducing capacity between periods was highly significant at the 0.01 level.

E.M.F. Potentials. The data obtained for the potentials are presented in Table I. The means and standard deviations of the m.v. (millivolts) observed for the four varieties ranged from 367 ± 29 for the Golden Delicious to 382 ± 18 for the York Imperial apples during the last 12 weeks of growth. The corresponding values obtained during 22 weeks of storage for the Golden Delicious and York Imperial were 349 ± 39 and 356 ± 40 m.v., respectively. The Rome Beauty and Red Delicious compared to the Golden Delicious and York Imperial had intermediate values during both growth and storage. As indicated in Table II, varietal and interaction influences on the potential were not significant, but the difference in potential between the growing and storage periods was significant at the 0.05 level. The potential evaluation should be a measure of the oxidative state of the fruit.

Water. The values obtained for the percentage of water in the apples are presented in Table I. These values are the means and standard deviations of nine biweekly determinations during storage from January 8 to May 1, and range from 85.9 ± 1.2, 85.3 ± 1.1, 84.8 ± 1.2 to 82.3 ± 1.1 for the Red Delicious, Rome Beauty, York Imperial and Golden Delicious varieties, respectively. As indicated in Table II, the varietal differences in water content are significant at the 0.01 level, due mostly to the low concentration of water in the

Golden Delicious. A comparison of the water determination by toluene distillation, using receiving tubes with values obtained by drying the samples in an oven at 100° C. to constant weight, was made on York Imperial, Red Delicious and Golden Delicious apples. These varieties were evaluated in duplicate or triplicate, and the means and standard deviation of ten determinations by the distillation and oven methods were 83.81 ± 1.51 and 86.11 ± 1.78 per cent, respectively. This difference is significant at the 0.01 level. A vacuum oven was not available for this study; the lower temperature recommended for the drying of fruit in a vacuum oven should give values that agree more closely with the true water content than the drying procedure used in the above comparison.

The rainfall during May, June, July, August, September and November at the West Virginia Horticultural Farm was 5.42, 3.52, 1.93, 9.38, 4.46 and 1.51 inches, respectively.

Summary

Apples of the York Imperial, Rome Beauty, Red Delicious and Golden Delicious varieties have been evaluated for their (*a*) capacity to reduce tetravalent cerium, (*b*) E.M.F. potentials, and (*c*) water content, as determined by toluene distillation and receiving tubes. The reducing capacity and potentials were evaluated during both growth and storage, and the water only during storage; at approximately biweekly intervals. The reducing capacity was greatest during growth, least during late storage and intermediate in early storage. The potentials were more positive during growth. A statistical analysis of the data indicated no significant variety or interaction influences on the reducing capacity or potentials of the apples, but that the variation in reducing capacity during growth, early and late storage was highly significant at the 0.01 level, and the difference in potentials between the growing and storage periods was significant at the 0.05 level. The variance in water content of the varieties of apples was significant at the 0.01 level. True water evaluations were shown to be significantly lower than those obtained by oven drying.

Acknowledgment

The writers wish to thank Mr. Edwin Gould, Superintendent of the West Virginia University Horticulture Farm at Kearneysville, West Virginia, for full cooperation during this study.

Literature Cited

1. Association of Official Agricultural Chemists. Methods of Analysis. 7th ed. 1950.
2. Blake, Charles E., and Shirley, Ray L. Oxidation, potentials, buffering, ash, and total solids of peaches. Bot. Gaz. 115: 180–185. 1953.
3. Snedecor, George W. Statistical methods applied to experiments in agriculture and biology. Iowa State College Press, Ames, Iowa. 4th ed. 1946.

Safflower — *Production, Processing and Utilization*

Safflower, grown formerly for the red dye from its flowers, is now a source of oil and livestock feed. In California an average of 30,000 acres have been grown each year since 1950. It has been both a dryland and irrigated crop. The oil has had a ready market for the manufacture of alkyd resins and drying oils.

P. F. KNOWLES

Department of Agronomy, University of California, Davis, California

Safflower (*Carthamus tinctorius* L.) made its debut many centuries ago among the crops useful to man. Then it was man's vanity that persuaded him to domesticate this plant, for he had discovered that the color within the flowers could substitute for saffron. Though synthetic dyes have taken over this role, safflower continues to play a part in the world's economy as an oil crop.

The status of safflower in the United States has been described a number of times, and it is not intended to repeat it here. The present paper will expand upon these accounts in two directions: one will be towards the status of safflower in other countries of the world; the other will be along the road it has traveled in California.

Distribution

Until recent years safflower was confined to regions of Asia, Africa and Europe where it had been grown for centuries. These included the margins of the Mediterranean Sea and the areas eastward into India and southward into Ethiopia. During the past 30 years, more particularly during the last 15, determined efforts have been made to

TABLE I

ACREAGE OF SAFFLOWER BY COUNTRIES* IN SELECTED YEARS

Country and area	Year	Number of acres	Reference
India			
Bombay	1900	500,000	(126)
Bombay	1948	416,298	Sikka **
Madhya Pradesh	1948	7,000	"
Hyderabad	1948	600,000	"
Turkey	Av. 1950–53	3,100	Tariman **
Israel	Av. 1949–54	3,511	Bar-Droma **
France	1949	7,400	Min. Agr.**
"	1950	4,900	"
"	1951	4,900	"
"	1952	1,200	"
"	1953	0	"
USSR	1932	121,000	(108)
French Morocco	1946	500	(13)
Egypt	Before war	2,500	(13)
"	Av. 1950–54	511	El-Sawi **

* Except USA.
** Personal communication.

establish safflower as an oil crop in many parts of the world. It has been difficult to obtain accurate data on areas of production, but those available to the writer are given in Tables I and II.

Asia. Safflower appears to have been established as a cultivated crop for the longest period in India and Pakistan. Its culture as a source of dye was centered in Bengal, the United Provinces and the Punjab (126). As an oil crop it was, and is, grown in the states of Bombay, Madhya Pradesh (formerly the Central Provinces and Berar) and Hyderabad. In these regions it is often found in association with such crops as wheat, barley and chick peas, being sown either as a border about the field or as a few rows alternating with a larger number of those of the main crop (6, 124, 126). Its purpose in such an arrangement seems to be to provide protection from stray cattle, sheep or goats. This association with other crops has made it difficult to obtain reliable statistics on production.

TABLE II

ACREAGE OF SAFFLOWER IN CALIFORNIA AND THE UNITED STATES*

Year	California		Yield, lbs./A.	Other states acreage	Total U. S. acreage
	No. of acres	Production (1,000's of lbs.)			
1946	.....	.....	....	2,000	2,000
1947	.....	.....	....	4,000 **	4,000 **
1948	.....	.....	....	15,000 **	15,000 **
1949	150	.....	....	40,000	40,000
1950	23,000	14,000	609	50,000	73,000
1951	17,009	15,000	882	10,000 ***	27,000
1952	42,000	47,000	1,119	15,000 ***	57,000
1953	45,000	52,000	1,155	20,000 ***	65,000

* Planted acreage (10).
** See (21).
*** These are believed to be about twice the actual values.

Safflower has been collected from the regions north of India and Pakistan and westward to the Mediterranean Sea, though in this area it is grown on a small scale and mostly for its flowers (65). In recent years it has become established as an oil crop in Israel and Turkey.

Europe. At one time it would appear to have been rather widely grown in Europe for its dye, and certainly was well established as far north as Alsace and southern Germany in the sixteenth century (109). There are meager reports suggesting that it was recognized as an oil crop in Germany as early as 1777 (109). Though it is frequently found in Spain (65), it is not grown there as a field crop. The most extensive acreage as an oil crop in Europe has been in southern Russia.

Considerable research has been done in Germany in evaluating safflower as an oil and feed crop, particularly just prior to and during World War II. No statistics could be found on commercial acreages in that country.

Safflower was introduced on a small commercial scale in southern France in 1943 (16, 67). At the present time production has almost disappeared because of damage by larvae of the safflower fly.

Africa. In isolated areas of North Africa, Egypt, the Sudan and Ethiopia, safflower is still grown on a small scale for its flowers. During World War II there was some production as an oil crop on a field scale in French Morocco (33). Recently in South Africa there have been successful trials of safflower on a field scale (112), but it is not established there as a commercial crop.

Australia. There has been considerable research in Australia both in the direction of evaluating and improving the crop and in that of utilizing the oil for paint products (90). Though some of this research was on a field scale and quite promising, safflower is not established there on a commercial scale.

North America. Safflower has been grown in Mexico for its flowers (127), its introduction to that country probably being made from Spain at an early date. The date of its introduction into the United States is not known, but rust was reported on safflower in Massachusetts in 1895 (28). The first comment on it as a field crop was made in California in 1903 (114).

The stimulus to real interest in safflower as an oil crop in North America arose out of research of Rabak and Claassen. Rabak grew yield tests in many areas of the United States during the years 1925 to 1935, and from these he determined the areas where it was adapted and developed information on its culture (92). As a consequence, there were a few thousand acres grown from 1930 to 1940. His work failed to establish the crop permanently, mainly because his varieties had a low oil content. Claassen continued the work of Rabak, but in addition developed higher yielding varieties with up to 36 percent oil in the seed (25). It was these "Nebraska" varieties that made the crop attractive to both farmers and oil-seed processors. Most of the acreage prior to 1948 was in Montana. The increase in 1948, 1949 and 1950 was largely in the eastern Colorado and western Nebraska areas. A processing plant was built at Longmont, Colorado, in 1949. With the financial failure of this processing plant after the crop of 1950, safflower has almost disappeared from that area. An unsuccessful attempt was made in 1954 to grow safflower on a limited acreage in east-central Colorado. This time moisture was inadequate. Much of the intended acreage was not planted, and very little of the planted acreage developed sufficient safflower to harvest. The establishment of safflower in California is described in the next section.

Canada has not grown safflower commercially, though it has been under test

for several years (28, 72). Efforts are underway to develop earlier maturing and better adapted varieties (51).

California. It is not known when safflower was first introduced to California, but it probably came with immigrants from the area of the Mediterranean Sea and Southwest Asia. It may still be found occasionally in gardens, where it is grown for its flowers. Shinn mentioned in 1903 (114) that safflower had been grown, presumably in garden plots, in the area of the Foothill Station (near Jackson) some years before.

Safflower was grown on a small commercial scale in 1937–38 in California (71, 99), but did not appear too promising. This was an outgrowth of the pioneer work done by Rabak. The crop failed because the oil content was low and yields were disappointing. It is of interest to note that the only dryland yield that Rabak obtained in excess of 40 bushels per acre was in the San Joaquin Valley under conditions of winter culture.

A decade later, California again followed the lead of research and commercial developments in the Great Plains. The initial impetus was a severe reduction in the acreage of cotton in 1950, which turned the interest of oil-seed processors to alternative crops. This time safflower remained in California in spite of its disappointing performance in the first year (Table II).

In 1949–50 most of the acreage was in the Imperial and southern San Joaquin Valleys. Agriculture depends entirely on irrigation in the Imperial Valley, and almost entirely so in the southern San Joaquin Valley. Since 1950 acreage has shifted to the Sacramento Valley and northern San Joaquin Valley, where safflower has proved to be very well adapted. In these areas the important winter crops are the small grains which are grown on both non-irrigated and irrigated land. In the latter case an irrigation is not given except occasionally in very dry years. They are usually planted just before or just after the first fall rains and harvested in May or June. Summer crops are irrigated. In this paper the term "dryland" refers to situations where irrigation water is not used on any of the crops in the rotation.

California is the only area of the nation where safflower is well adapted and where processing plants are numerous. Two processing companies, the Oil Seed Products Company of Fresno and the Pacific Vegetable Oil Corporation of San Francisco, played a large part in the establishment of the crop in 1949–50, though only the latter has processed it since that time. More than a guaranteed market has been provided: it was necessary to actively "promote" the crop in terms of providing information on it before and after planting. This took and still takes the form of farmer meetings, personal contacts with individual growers, and the assistance of trained agronomists through the entire growing season. Beyond this it has been necessary to develop and maintain a market for both the oil and the meal.

Botany

Critical Botanical Characteristics. Only those features of safflower that have a bearing on its success or failure will be discussed. Detailed descriptions of the plant and seed are available elsewhere (25, 65, 109).

Its thistle characteristics have sometimes given the impressions that it is a possible weed, that it can successfully replace other crops in poor locations, and that it can be grown with careless methods. These impressions were prevalent in California at one time, and occurred elsewhere (62, 70). In all cases they are without basis in fact.

The seedling stage is critical. In this stage safflower grows slowly, and the leaves lie close to the ground. It is at

this stage that weeds are highly competitive. This is particularly true of fall plantings in northern California, where the winter rains will usually prohibit cultivation to control rapidly growing weeds.

A second critical stage can occur after flowering when plants have failed to produce a satisfactory crop of seed on large vigorous plants. In these instances it would appear that there was insufficient soil moisture, since they have usually occurred under dryland farming when winter rainfall was rather low, and when a cereal crop of the previous year had exhausted the soil of moisture.

The deep root penetration may have some bearing on the behavior of safflower. Pugsley and Winter (90) found safflower roots to a depth of seven feet, whereas wheat roots in the same area penetrated to four and one-half feet. Doneen (unpublished) has analyzed soil samples at different depths in a safflower plot at Davis and found that water was being removed down to eight feet.

Varieties. The most comprehensive study of the variability in domestic safflower has been provided by Kupsow (65) who felt that its most ancient development had occurred in two regions, one comprising northern India and Afghanistan, the other the area adjoining the Nile and north of the mountains of Ethiopia. There are available detailed descriptions of varieties grown in India (48, 56, 101) and of those being utilized in some safflower improvement programs (25, 26, 66, 108, 109).

It is not without significance that the commercial varieties in the United States have been selections from introductions obtained directly from Africa or Southwest Asia. Considering the limited number of introductions, safflower would seem to have given a rather good account of itself in competition with crops that have been established for a long period in California. More extensive collec-

FIG. 1. Top to bottom: *C. oxyacantha* from India; *C. lanatus* from near Petaluma, Sonora, San Luis Obispo and Brea, California; N10; N6.

tions are needed from abroad, particularly so because Nebraska varieties are now being shipped back to the Old World, perhaps to replace indigenous safflower materials. The latter may contain germ plasm valuable to plant breeders in the United States and other areas of the world.

The varieties that have been most successful in California are N6, N10 and N852 (Table III), all of them Nebraska varieties. N10, a selection of N852, has replaced the latter because it has a higher oil content. N10 is recommended where no surface irrigation is used and is grown on about 75 percent of the acreage (116). N6 is used where irrigation is practiced or where there are abundant supplies of soil moisture. They have shortcomings: all are susceptible to rust; all are susceptible to Phytophthora root rot, N10 and N852 particularly so; all are susceptible to Botrytis blight; and N6 is sensitive to even small amounts of boron. The rust-resistant variety, Western Oilseeds 14 (116), has not proved too successful because it is not so high yielding as N6 or N10 where rust is absent or present in small amounts. Rust-resistant varieties will be available for commercial production in the near future (82). There is a need for earlier safflower varieties in California to compete better with cereal crops. Greater resistance to cold for fall plantings and more rapid growth in early stages of spring plantings would be desirable. Spineless varieties would be preferred if they had the same yield and oil content as spiny varieties.

The single improvement in safflower that would do much to guarantee its permanence in American agriculture is a higher oil content. At the present time, for every increase in oil content of one percent, industry can afford to pay $2.00 to $2.50 more per ton for the seed. An increase in oil content from the present 36 to 37 percent level to 40 to 41 percent would permit minimum prices of $78 to $80 per ton instead of the present $70. Such safflower will have very thin hulls, so thin that many of the seeds will be brown instead of white. It will yield a meal with a higher protein content.

In this respect the research by Claassen into relationships between oil content and other plant characters is important (23). As expected, a high hull content was correlated with low oil content ($r = -0.77$). A simple and relatively accurate estimate of oil content was achieved

TABLE III

YIELDS AND OIL CONTENTS OF SAFFLOWER VARIETIES AND FLAX IN TESTS AT DAVIS, CALIFORNIA

Date sown	Yields, lbs./A.					Oil content in percent **				
	Flax *	N6	N8	N10	N852	Flax *	N6	N8	N10	N852
Jan. 30, 1948	....	....	....	....	3022	...	...	...	...	32.7
Feb. 16, 1949	1323	3166	2696	....	3749	37.3	32.3	33.8	...	34.1
Nov. 29, 1949	1769	3769	4565	4342	4324	38.1	30.2	32.9	32.6	31.4
Mar. 11, 1950	1690	1952	2140	2544	2564	38.0	28.4	33.2	33.6	33.2
June 8, 1950	....	2418	2749	2456	2528	...	31.1	32.5	34.2	32.6
Jan. 2, 1951	1234	3799	3421	4066	3879	39.5	33.7	38.5	35.9	33.5
Feb. 23, 1951	....	3370	2661	....	3373	...	32.9	37.7	...	34.0
Apr. 4, 1951	1084	2382	2053	2574	2342	36.7	31.0	37.3	35.6	32.2
Dec. 22, 1951	....	2640	1655	2687	2780	...	32.9	35.1	34.6	33.0
Apr. 2, 1952	....	2175	2420	2428	2230	...	32.2	35.0	36.1	34.0
Feb. 6, 1953	1780	1845	....	2750	3385	39.3	34.5	...	38.1	34.6

* Variety Punjab in test sown Feb. 16, 1949, and Punjab 47 in remaining tests.
** Using Waring blendor technique (54).

by the thumb-nail test—the easier it is to cut the hull, the higher the oil content. Though there was a highly significant correlation between oil content and both seed size ($r = 0.22$) and spininess ($r = 0.20$), it was felt that they were too low to permit their use as criteria of high oil content. Spineless segregates were found with 39 percent oil.

Hybrid Varieties. Highly cross-pollinated selections have been found that give more vigorous open-pollinated than selfed progeny. They could be used in the production of hybrid varieties in somewhat the same manner as in sunflower (91). Though safflower is frequently classed as a cross-pollinated plant, most studies indicate that the amount of crossing will vary a great deal with different selections (22, 48, 53, 66). Some inbreds with high yield and high oil content were found by Claassen to have less than five percent outcrossing (22). His field observations and caging experiments indicated that insects were responsible for most of the pollen transfer.

Related Species. The genus *Carthamus* is confined to the areas of Asia, Europe and Africa where cultivated safflower has been or is being grown. Species are particularly abundant in North Africa. A study is under way at this station to determine the relationships of some of these species to *C. tinctorius*, *C. lanatus* L. and *C. oxyacantha* Bieb.

C. lanatus occurs over the entire range of the genus. In California it is found as an introduced weed in a few areas, either on range lands or along roadsides. Some of the collections appear like *C. baeticus* (Boiss & Reut.) Nym. Collections of these wild materials will be compared with introductions of *C. lanatus* from abroad. *C. lanatus* has 32 pairs of chromosomes (86).

The wild species most closely related to cultivated safflower is *C. oxyacantha*, found in northern India and Pakistan and westward into Turkey (109). Like *C. tinctorius* it has 12 pairs of chromosomes and they cross readily (32). Both are susceptible to rust (88). Research is necessary to determine whether *C. oxyacantha* is the progenitor of *C. tinctorius* or a segregate from a cross of *C. tinctorius* with some other wild species. Deshpande (32) has suggested that *C. oxyacantha*, though considered to be a troublesome weed in the Punjab, may have some value as an oil crop on waste lands. Seed of this species has been used in India (126) as a source of oil for the manufacture of Afridi wax cloth. The oil content is rather high, being reported as 27.2 (32) and 28.0 percent (40).

Adaptation

Because California has a Mediterranean type of climate, it is not surprising to find safflower well adapted to many parts of the State. However, it has proved to have rather definite requirements, particularly with respect to its moisture relations. These requirements have limited its distribution in other areas of the United States to the western Great Plains and the Pacific Northwest.

Temperature. The minimum temperature tolerance of safflower has not been determined accurately, but it will vary with the stage of development and with the variety. In the seedling stage at Davis, when the plants had been hardened by a long period of cool weather, a temperature of 19° F. killed approximately 50 percent of the seedlings of N852 but did not injure N8. On the other hand, after a period of rapid growth in Imperial Valley, when N852 and N8 had reached a height of 18 and 11 inches, respectively, N852 was almost completely killed by temperatures down to 24° F., but N8 was damaged very little. In Idaho temperatures of 28° F. damaged all varieties, but to different degrees, when they were about four inches high (58). After flowering safflower is damaged by a few degrees of

frost. These observations have not indicated the minimum temperature tolerance of the most hardy varieties in seedling stages, though Claassen has placed it in the range of 10 to 15° F. (25).

The minimum temperatures for germination have been determined by Scheibe (108). He found that practically no germination occurred at 36.3° F., and almost complete germination at 41° F. The average time for germination to occur at temperatures of 41.0°, 48.2° and 59.0° F. was 16.2, 8.7 and 3.7 days, respectively. Under field conditions in California, it has taken up to 30 days for seedlings to emerge during the months of December and January if temperatures were low.

Safflower has not been observed to suffer from high temperatures in California, provided there were ample supplies of soil moisture. However, it has not shown promise as a summer crop.

Moisture. The moisture requirements of safflower are often expressed in terms of its reaction to disease. In areas of California subject to fog safflower has grown vigorously until the blooms appear, when the heads are attacked by Botrytis blight (*Botrytis cinerea* Pers.) (47, 60). Scheibe has observed the same disease in Germany but in association with a secondary *Fusarium*-like pathogen (108). The head rot induced by these diseases precluded the production in Germany of most of his introductions from areas of Southwest Asia and the Mediterranean Sea. The fact that his introductions from European countries were resistant to head rot would indicate that it may be possible to develop varieties for the United States that are more tolerant of high humidities.

Other diseases are also favored by high humidities. Frequent showers and heavy dews in the Great Plains have been followed by severe infestations of Alternaria leaf spot in safflower grown on irrigated land. The spread and severity of rust in California appears to be favored by the combination of warm temperatures and high humidities at the end of the rainy season.

Root rots are encouraged by excessively high levels of soil moisture. Damage from Phytophthora root rot in California has often been severe on susceptible varieties following an irrigation, particularly if the soil is impermeable. Pythium root rot was found in Canada on irrigated land, but not on dryland (29). The Sclerotinia wilt disease has been more abundant in India in years of high rainfall (52).

There have been harmful effects from high rainfall and humidities apart from disease. Excessive rain at flowering time has adversely affected pollination (92) and after flowering has discolored the seed or prevented them from filling (112). A prolonged period of rain after the crop is ripe will germinate seed in the head. This has been noted in France (70) and in experimental plantings of the writer in California.

Safflower has earned a reputation as a drought-resistant plant. It has lived up to this reputation in northern California, where it may advance from the bud stage in May through to maturity in August without rain or irrigation. This would appear to be true also of safflower in Asia and North Africa. It must be stressed, however, that this drought resistance is dependent upon adequate supplies of moisture in the soil. In fact the drought resistance may simply be a measure of the depth and extent of the root system of safflower. Where the soil has not been moist to a depth of three to four feet at planting time, safflower heads have failed to produce a satisfactory seed yield (25). Without this reserve of moisture in the Great Plains, there should be 11 inches of rainfall during the growing season to avoid a crop failure. Presumably it was lack of soil moisture that permitted drought to be

the most frequent cause of safflower failures in the Great Plains from 1925 to 1933 (92). In Turkey safflower following small grains gave a very poor yield, though it was considered to be outstanding for its drought resistance (109). In northern California a heavy rain in mid May has been more beneficial than the same amount just before or after planting, presumably because it restored the supplies of moisture taken out of the surface layers of the soil by the vigorously growing safflower. The fact that 30 to 50 percent of the present safflower acreage in California is grown on land with a high water table will underline the importance of soil moisture in explaining the drought resistance of safflower.

It has been rather surprising to find very few references to the use of irrigation water on safflower in other countries, though it has been grown under irrigation in northern India (124) and appeared promising when irrigated in South Africa (112). Apparently it has been almost entirely a dryland crop. For this reason one might expect that it would not be particularly adapted to irrigated agriculture. This is true of many varieties, particularly if surface irrigation is used on impermeable soil. Certainly it was generally true of the first semi-commercial and commercial trials of safflower under irrigation in Nebraska (26) and California. At the same time it must be admitted that much of the reputation of safflower as a successful crop in California has depended upon its performance on irrigated land. This includes situations where pre-irrigations and surface irrigations are used, where sub-irrigation is practiced, and where safflower is grown without supplemental water but after an irrigated crop. When grown with surface irrigation in California, safflower will require at least one, and preferably two, more irrigations than barley. Maximum yields will depend upon 18 to 25 inches of soil moisture.

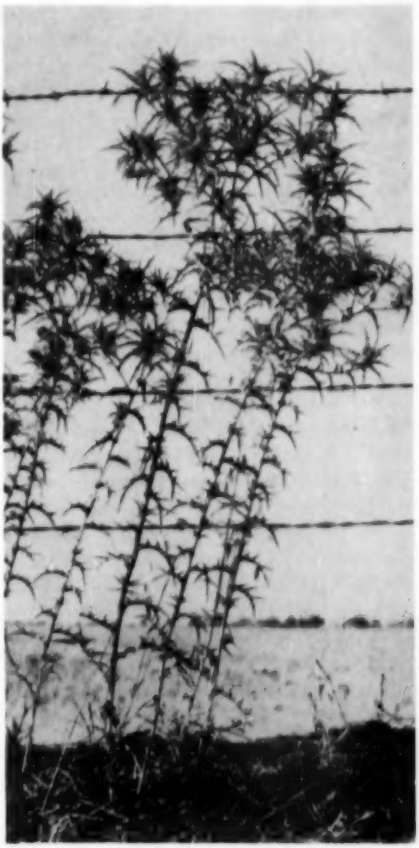

FIG. 2. Wild safflower growing on a roadside near Stockton.

Other Climatic Factors. The minimum length of the growing season is usually stated as 120 days. This would apply in California if safflower were planted in May and June. Fall plantings will require more than 200 days (Table IV).

Safflower has frequently been observed to be quite resistant to damage by wind. This is expressed in its ability to stand erect and to retain the seed in the head.

Hail will damage well developed safflower plants much less than other crops, but they are very susceptible in the stage

TABLE IV

DATA FROM A DATE OF SEEDING TEST OF THE SAFFLOWER VARIETY N852 GROWN AT DAVIS, CALIFORNIA

Date sown	Date first bloom	Date ripe	Days to maturity	Height in inches	Yield, lbs./A.
Nov. 17, 1949	May 29	July 22	247	59	3693 *
Dec. 14, 1949	June 1	July 26	224	55	4073
Feb. 2, 1950	June 5	July 29	177	50	3730
Mar. 16, 1950	June 13	Aug. 3	140	41	2845

* Stand thinned by frost.

after stem development until flower buds are well formed (25).

Soil. The soil requirement of safflower cannot be stated precisely, though there are many references to this subject. There seems to be good agreement that it is a crop for deep, well drained soils (25, 37, 77, 92, 109). Certainly it has not been too successful on the shallow upland soils of the Sacramento Valley in California. This also has been true in Turkey on similar soils (109). In the Punjab it prefers the lowlands unless the uplands have plenty of rain (97).

Most observations and research would support the point of view that it requires a fertile soil particularly well supplied with nitrogen. In France from 1943 to 1947 there was an increase in acreage on the better soils and a decrease on the poorer soils (67). On the other hand, Rabak noted that soils extremely rich in nitrogen have produced luxuriant vegetative growth but few flowers (92), and Mauron believed excessive amounts of nitrogen would depress yields (70). Except where vigorously growing fields have exhausted the soil of moisture, the writer has not seen such a situation in California. On the other hand, many fields have been seen where growth was depressed by lack of nitrogen.

The presence of lime has been considered beneficial (92). Scheibe found that acid soils had an adverse effect, and he stressed the necessity of a calcareous type of soil in both Turkey and Germany (108, 109).

Perhaps the greatest confusion exists with respect to the texture of soil best suited for safflower. The preferred texture has ranged from open sandy soils (48, 126), through clay loams and sandy loams (92) to clay (75, 111). In California safflower has been grown successfully on a wide variety of soil types. Sandy soils have not been too satisfactory unless they were supplied with irrigation water and fertilizer. Medium-textured soils have been best where surface irrigation was used. Heavier textured clay soils have been preferred under dryland conditions because of their greater water-holding capacity; they have also given high yields of safflower where sub-irrigation has been practiced or where there was a high water table. Safflower has adapted itself very well to the heavy clay soils that grow rice (3), where it is grown without supplemental irrigation water.

Heavy soils with poor water penetration present a problem if surface irrigation is practiced (92). Where water stands for even a short period of time on safflower, particularly if temperatures are high, the plants will be killed. This has also been true of early plantings where winter rains have caused flooding of portions of safflower fields. Heavy soils will develop a crust rather readily following a rain, and this has sometimes reduced stands (90). On the extremely heavy soils where rice is grown, it has been difficult to prepare a suitable seed bed; the soil has been either too wet to work or too dry to germinate the seed.

Safflower appears to have about the same tolerance to alkali as barley if it is grown under dryland conditions (25). Under irrigation, particularly where surface irrigation is used, it is less tolerant than barley (92).

Production

Only a few of the more important details of the production of safflower will be considered here, and the discussion will apply in particular to California. Since it is comparatively new in that State, there is still much to be learned about its culture. There is available elsewhere such information for the western Great Plains (25, 115, 129), the Pacific Northwest (54, 58, 79, 81) and California (60, 82).

Rotation. Under the diversity of agriculture prevailing in California, it is not possible to discuss in detail the place of safflower in a rotation. In general, however, it may be considered a replacement for barley and occasionally for wheat or oats. The moisture requirement may be met by growing it after an irrigated crop or on fallow under dryland agriculture in northern California. Otherwise there should be sufficient rain to wet the soil to a depth of four feet before planting.

Safflower has often given returns superior to small grains in spring plantings. This is particularly true after February 15. In some recent years late plantings of cereal crops have been attacked by a virus disease termed "yellow dwarf" (80), and this has magnified the difference in yields between safflower and barley. The nature of the fall weather has had an important bearing on the relative acreage of barley and safflower. With a long dry period after the first fall rains, farmers tend to put most of their available land into barley. But with continuous wet weather until February there has been more interest in safflower. In Israel under similar circumstances the decision has been the same (84).

Safflower appears to be well established in some areas of northern California where rice is grown. After a rice crop the land frequently does not dry out enough to be cultivated before the winter rains. In this event it will remain wet until rather late in the spring and too late for small grains. Safflower has benefited from the abundant soil moisture supply in such soils and has not required supplemental water. Safflower is able to dry out such soils to a considerable depth, which improves them for succeeding crops of rice. It has been suggested as a crop for areas growing rice in France (67).

In some California situations safflower would not be a desirable substitute for barley or other small grains. Safflower could not be used in a double cropping system because it matures too late in the summer to permit a second crop to be grown. Where small grains are planted in dry soil before the winter rains, safflower could not be recommended because of competition from winter weeds and possible frost damage. Following safflower, one of the small grains would be a better choice because of the danger of serious damage from safflower rust. It has already been stated that barley would be preferred where there is a scarcity of soil moisture or where the soils are shallow and low in fertility.

Safflower does not have a greater adverse effect on the subsequent crop than small grains. In the Great Plains barley yields were higher after safflower than after wheat (25), and the same was true in Idaho where wheat followed both safflower and oats (58). Volunteer safflower plants are not strongly competitive but have sometimes been seen in barley fields in California. Usually any shattered safflower seeds germinate with the first fall rains, and the seedlings are destroyed in preparing a seedbed for the succeeding crop.

In the Great Plains where summer fallow has alternated with winter wheat, downy brome (*Bromus tectorum* L.)

and hairy chess (*Bromus commutatus* Schrad.) have sometimes become troublesome because they emerge after the wheat is planted. Safflower, because it is spring-sown, will tend to control these weeds (25).

Planting. Seedbed preparation is similar to that used for wheat and barley. The final operations should take place just before planting to avert development of weed seedlings ahead of the crop. Established seedlings of volunteer small grains or weeds should be completely killed. It is important that the soil moisture be near the surface.

The optimum planting date cannot be stated in simple terms. In the southern San Joaquin Valley and the desert valleys of southern California and Arizona, where winters are mild and the spring early—these are areas where cotton is grown—plantings should be made from November to early January (60, 69, 71). Such plantings will depend largely or almost entirely on irrigation water. Experience in New South Wales, Australia, favors fall plantings made the same time as wheat (90). In French Morocco fall plantings are recommended, with the second choice being as early in the spring as possible (13, 33). Safflower is sown in India from September to November (88, 124).

In northern California plantings should be made as soon after February 1 as possible if the soil is well supplied with soil moisture or if supplemental irrigation water is supplied. Planting at this time will permit winter weeds to be destroyed and will allow the safflower to become well established before the summer weeds become serious. Earlier plantings have given high yields (see Table IV) but they have been exposed to rather low temperatures and competition from weeds. Under dryland conditions, where moisture supplies are scarce, plantings should be delayed in some cases to April 1 to avoid developing a large plant that will exhaust the soil of moisture before seed production (82).

In the Pacific Northwest and the western Great Plains of the United States and in adjacent areas of Canada, all the available data support the recommendation that safflower be sown as early as possible in the spring (20, 58, 72, 79). However, soil temperatures should be above 40° F. and danger of temperatures down to 15° F. should be passed (25). Rabak found that cold wet weather in early spring adversely affected germination and growth (92).

It also is difficult to make precise recommendations on seeding rates. For California the following rates are used: under irrigation, 40 to 50 pounds per acre in solid seedings, and 20 to 25 pounds in rows; under dryland, 25 to 35 pounds per acre in solid seedings, and 15 to 20 pounds in rows. The higher rates give better weed control; lower rates are necessary when moisture supply is deficient. Heavier stands will give thinner stems, less branching and easier harvesting. The common practice has been to use solid seedings with the rows 12 inches or less apart. One exception is where cultivation is necessary to control weeds, when the rows are spaced about 20 inches apart. The other exception is where the crop is furrow-irrigated, when the rows may be either uniformly 20 to 30 inches apart or in pairs of rows 14 to 16 inches apart on beds spaced 40 inches from center to center—the latter is a common practice with many crops in California because it greatly facilitates furrow irrigation.

Good stands have been obtained both by drilling and by broadcasting from the ground or air. It is important, however, that the seed be placed in moist soil. For this reason late plantings, when the soil is drying out, should be made with a drill. Preferably the seed should not be planted deeper than two inches, though seedlings will emerge from a

depth of four inches if a crust does not develop on the surface of the soil.

Seed treatment with a fungicide is recommended because it has given partial or complete control of some diseases (25, 90). Lindane should be used with the fungicide if it is necessary to control wireworms.

Irrigation. Safflower has been grown in California under a variety of types of irrigation. At the present time probably less than ten percent of the crop is actually irrigated, though a much larger amount benefits from irrigations given to the previous crop.

The flood, or border, system of irrigation has been the least desirable, since it has often led to excessive ponding at the lower ends of the checks. Such ponding has resulted in the death of plants, due either to the flooding itself or to high incidence of Phytophthora root rot. Damage has also occurred without ponding where soils were impermeable or where plants were under stress from lack of water.

The furrow system of irrigation may be used in California and is also used in the Great Plains area. Row spacings have varied, depending on the row spacing for other crops grown on the same farm. There has been little use of the sprinkler system of irrigation. Sub-irrigation has given excellent results. It has provided the water necessary for maximum yields without the disadvantages of other methods.

A pre-irrigation has been given safflower in desert areas of California where it is sown in the late fall and where winter rains are not sufficient to produce a crop. Under such conditions three to five crop-irrigations may be given if there is no winter rain. In northern California under conditions of 16 to 20 inches of winter rain, two irrigations should be sufficient for maximum yields. Three irrigations are suggested for the western Great Plains (25).

FIG. 3. Effect of date of seeding on height of safflower in 1951–52.

Fertilization. There is a scarcity of information on the fertilizer requirements of safflower. In Washington a response to nitrogen was obtained in two out of three years, and a low rainfall in

the third year may have precluded a similar response (54). Field observations in California would indicate that safflower requires at least as much nitrogen as small grains and often more. In Australia superphosphate improved yields (90). It is suggested that it be fertilized like maize in South Africa (112). Carefully controlled greenhouse studies of the response of safflower to different levels of nitrogen, phosphorus and potassium unfortunately did not include other crops for comparison (104, 106). There was a greater response to nitrogen than to phosphorus.

Weed Control. Rotations and proper timing of tillage operations have been the only procedures used in California to control weeds, since hand hoeing and chemicals are too expensive.

In the Great Plains area weeds that start after safflower is planted have been successfully controlled by light cultivations (25). The first of these is usually done with a stiff-tooth harrow just before the seed leaves appear above the surface of the ground, with the cultivations running crosswise of, or diagonal to, the rows. To be successful the seed bed must be level and free from clods. Where the seed is sown in a furrow, the cultivation will bury the seed too deeply for proper germination. This cultivation may be repeated when the safflower stems are three to six inches high. Rotary hoes, finger weeders and harrows have been used for this purpose. These cultivations are successful only where the weed seedlings are small. Where the safflower is sown in rows, cultivations are usually done in the same manner as for other row crops, though an early cultivation may be done crosswise of the rows.

The only herbicide that has not injured safflower in the writer's experiments is IPC (isopropyl N-phenyl carbamate) (60). This herbicide has given control of some winter weeds, including wild oats (*Avena fatua* L.). An IPC application, to be effective, must precede rain or irrigation to move it into the root zone. However, it would cost seven to ten dollars per acre to apply and has not been used commercially. It might be feasible, however, in row plantings if a narrow band were applied to the row and cultivation used to control weeds between the rows. Kerosene and a fortified oil at 100 gallons per acre did not injure safflower appreciably in one test and have been effective in controlling some weeds, but they are even more expensive than IPC. 2,4-D (2,4-dichlorophenoxyacetic acid) is extremely toxic to safflower in seedling stages, but less so when flowers have appeared (25, 60). *C. oxyacantha* showed a similar reaction to Phenoxylene (2-methyl-4-chlorophenoxyacetic acid) in early and fruiting stages (76).

Harvest. Safflower has not been difficult to harvest with equipments used for wheat or barley, except that the cylinder speed should be reduced and cylinder-concave clearances increased to a point where very few cracked seeds occur. The speed of the reel should be the same as the forward movement of the combine. It should be harvested when ripe. Delays in harvesting have not led to loss from shattering, but delays have permitted the stems and branches to become so brittle that they broke into small pieces on threshing and were difficult to remove from the seed. Seed should not be stored if it contains more than eight percent moisture.

In France and French Morocco the introduction of the combine harvester has permitted safflower to become established on a field scale. When harvested by hand, the spines were disagreeable and the large bulk of the plants made them susceptible to movement by wind.

Yields. Safflower seed yields are reported to range from 350 to 1500 pounds per acre under dryland conditions. In

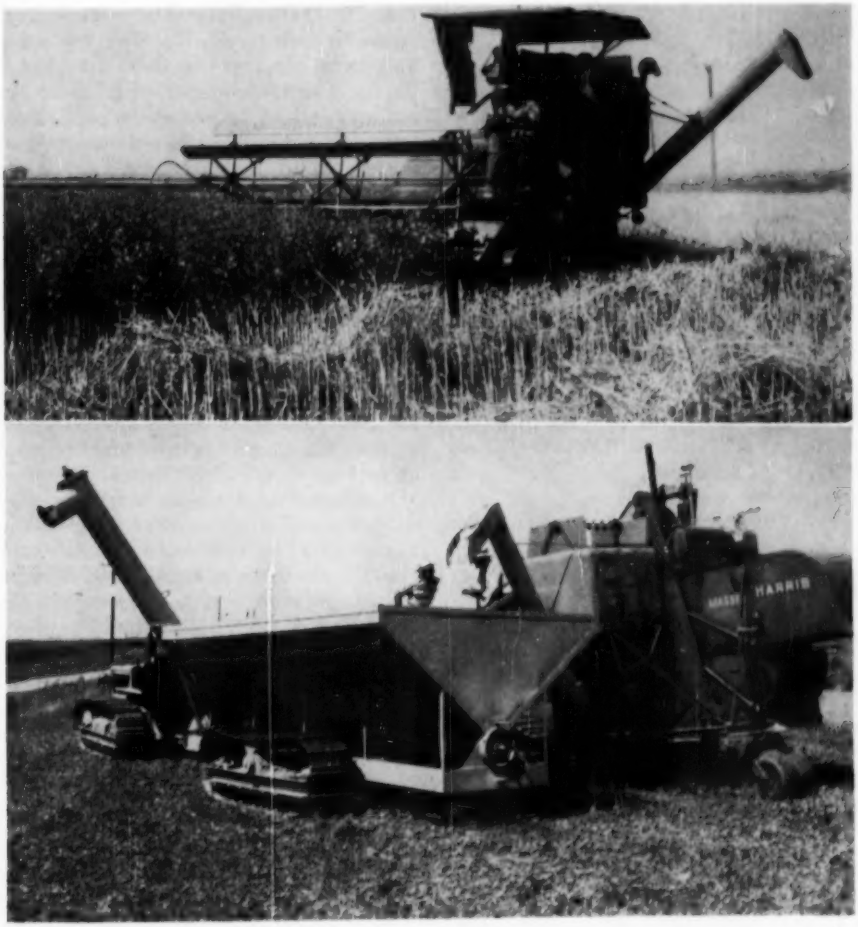

FIG. 4 (*Upper*). Harvesting safflower with a combine near Meridian, California, 1951.
FIG. 5 (*Lower*). Unloading seed from a combine into a tank designed to transport rice from the field.

the western Great Plains 750 to 1200 pounds may be expected on fallow land, and 350 to 750 pounds per acre following small grains (25). Under very favorable conditions yields have reached 2,000 pounds per acre. A similar range would appear to be true of the Pacific Northwest (79). Experience in France, French Morocco, Australia and South Africa has been similar. Under extremely dry conditions, with insufficient reserve of moisture in the soil, yields have been less than 350 pounds per acre. The situation in California is not greatly different, with the range being in terms of 250 to 2800 pounds per acre (59, 82). Yields up to 3400 pounds per acre have been obtained in semi-commercial tests in Germany. Comparisons of safflower with other crops are scarce. Winter wheat in

Australia gave 2460 pounds per acre, whereas safflower gave 1586 pounds (90). In eastern Oregon and Washington the yields of spring-grown safflower have been one-half to two-thirds of those of fall-sown wheat (1, 54). In Nebraska safflower was believed to yield 50 to 60 percent as much as winter wheat after fallow, but about the same as or higher than wheat after wheat (25).

Under irrigation, yields in the Great Plains may be expected to lie between 1,750 and 2,750 pounds per acre, and sometimes as high as 4,000 pounds per acre (25). The same range may be expected in California (59, 82), though a yield of 4,800 pounds per acre has been obtained. The yields of safflower grown under irrigation at Davis have been above 2,000 pounds per acre (see Table III). Yields of around 3,000 pounds per acre are expected on fertile irrigated land along the lower and middle Snake River Valley of Idaho (58).

Costs. Under dryland conditions the cost of growing safflower has been similar to or slightly higher than that for barley. If safflower is irrigated for maximum yields, production expenses will be higher than those for barley in terms of the costs of at least one and probably two extra irrigations.

Disease

Rust. Rust (*Puccinia carthami* Corda.) has been reported in practically every instance where safflower has been grown experimentally or commercially. It is widespread in California, but has not caused severe reduction in yield where it attacked the above-ground portions of the plant. Where safflower has been grown after safflower, however, rust has been a serious root and crown disease of seedling plants and has seriously reduced stands. It has behaved similarly in other areas (110).

Rust teliospores are carried on the seed and are particularly abundant on those with a pappus (31). The teliospores germinate shortly after the seed and infect the cotyledons of the young plant. The urediospores, which are dark red, are formed on the green plant and spread the infection. They are not transmitted long distances by wind (31, 67). Urediospores on the seed will not transmit the disease (15).

There are reports (31, 121) of complete control of rust by seed treatments, but Schuster and Christiansen found complete control only with small numbers of spores on the seed. Though all safflower seed grown commercially in California is treated with a fungicide, there are always a few plants infected by rust. Seed treatment, of course, gives no control of soil-borne spores.

Rust-resistant varieties have been developed for California (82). However, Thomas (personal communication) has found them to be susceptible to a race of rust observed in only one location in this State in 1954. This would appear to be the only report of variability in *P. carthami*. There are reports of rust being caused by other pathogens (28, 88).

Other Leaf Diseases. Leaf spot caused by *Alternaria carthami* has been the most common leaf disease in Nebraska (25) and has been particularly severe in irrigated plantings with heavy dews or frequent showers in July or August (27). On the seed it will cause seed rot and damping off of seedlings, but this phase of the disease can be controlled by seed treatment with Ceresan M (ethyl mercury *p*-toluene sulfonilide) or New Improved Ceresan (ethyl mercury phosphate) (119).

Leaf spot diseases have been caused by *Ascochyta carthami* Kvashnina (30), *Ramularia carthamicola* Darpoux (30), *Ovularia carthami* Darpoux (30), *Septoria carthamicola* Tropova (30), *Septoria carthami* Mour. (34, 72, 92) and *Macrosporium* sp. (92). Anthracnose (*Gloesporium carthami* Hore and Hem.)

on safflower has been described in Japan (92).

Mildew (*Erysiphe chicoracearum* f. *carthami* Milovtzova) has been observed on safflower in France (30), where it caused variable damage. The relation of Botrytis blight (*Botrytis cinerea* Pers.) to the adaptation of safflower in California has already been discussed.

Root Rots. *Phytophthora drechsleri* Tucker (36), the pathogen that has caused the most damage to safflower in California, has already been referred to in its association with irrigation and soil type. It was particularly severe in 1949–50 (118, 120) when safflower was grown for the first time on a large commercial acreage in California. Damage is confined almost entirely to land that is being or has been surface irrigated.

Little damage occurs in the seedling stage, and Thomas (122) believes this is because of low soil temperatures at that time of year. Damage may occur at any stage after the first irrigation and is manifested by the entire plant drying up very quickly. Varieties have different levels of resistance; N852 and N10 are particularly susceptible, while N8 is resistant (122). All varieties were susceptible at high temperatures. *P. cactorum* (L. and C.) Schroet. and *P. parasitica* Dast. are also parasitic on safflower in the United States (120), and *P. palmivora* Butler in Venezuela (68) and India (8).

Root rot caused by a *Pythium* species has occurred in Canada on irrigated land but not on dry land (29). Symptoms are similar to those of *Phytophthora* root rot. Varieties differ in their resistance to it. A root rot caused by a species of *Fusarium* has also been observed in Canada (72). The most serious wilt disease in India is that caused by *Sclerotinia sclerotiorum* Man. (52).

Injury to safflower by Verticillium wilt (*Verticillium albo-atrum* R. and B.) has been observed in California (47). The

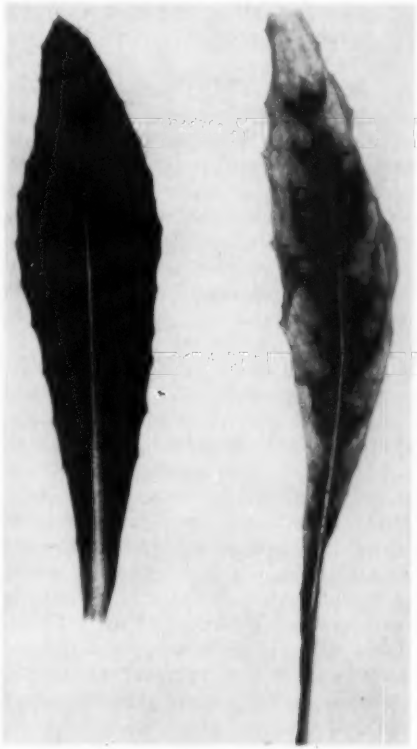

FIG. 6. Boron injury on right leaf.

woody portion of the stem became brown, and leaves bleached out or turned brown. Margins of leaves were attacked first, followed by bleaching of inter-veinal tissues. Symptoms were present on the lower leaves before the upper ones. It has been observed only in fields that had previously grown a susceptible crop such as tomatoes.

Boron. Boron injury has been found on the safflower variety N6 (47). The most obvious symptom of this disease is necrosis of the leaf margins (Fig. 6) which progressively affects more and more of the margin until the entire leaf is diseased. It has been observed in a number of areas in the lower part of the Sacramento Valley, particularly in areas

where boron toxicity has been observed in a number of crops.

Insects

In California insects have been of minor importance on safflower. Lygus bugs (*Lygus* spp.) are perhaps the most prevalent pest but have caused damage of economic consequence only to late-sown fields. Damage is evident on the heads, which may fail to develop or may be partly discolored. Control measures are suggested when the number of insects are two to five per sweep, and may be accomplished with DDT (dichloro-diphenyl-trichloroethane). The most effective application has been an airplane spray of one quart of 25 percent DDT in ten gallons of water per acre. Wireworms (chiefly *Limonius* spp.) have caused thin stands but have been controlled by treating the seed with lindane (gamma isomer of benzene hexachloride) at one ounce per 100 pounds of seed. A fungicide should be applied with the lindane. The bean aphid (*Aphis fabae* Scopoli) has been present in greater numbers in early spring, with damage confined to single plants or to edges of fields. Control usually has been unnecessary but may be accomplished with 40 pounds per acre of a dust application of either 4% Malathon (0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate) or 2% Parathion (0,0-diethyl 0-*p*-nitrophenyl thiophosphate). The larvae of the sunflower moth (*Homoeosoma electellum* Hulst) have caused occasional damage.

Insects have not been too important in the Great Plains area. It has been noted that grasshoppers chose small grains in preference to safflower, though severe damage to safflower has been caused by this pest (25), the damage occurring usually after the harvest of small grains and on the margins of fields. The clover leafhopper has been observed in safflower, but never in amounts to warrant control measures (25, 26).

Other areas have also reported insects on safflower. In South Africa it is susceptible to eelworm attack (112). In Israel the larvae of a species of *Heliothis* caused extensive damage to soft buds (84). In the same country two species of weevils and several kinds of flies infested the heads as they matured, destroying up to 20 percent of the seeds. In Germany heads of safflower infected by *Botrytis* and *Fusarium* contained larvae of the gall gnat (108). The larvae of a large greyish weevil (*Larinus flavescens* Germ.), which attack the inflorescences of thistle and artichokes, have caused damage to safflower in France (39, 67). The larvae of both the painted lady butterfly (*Vanessa cardui* L.) and the moth (*Chloridea* (*Heliothis*) *peltigera* Schiff.) have eaten the leaves, terminal shoots and buds (39). Aphid damage has been reported in India (64).

The insect that has caused the most damage to safflower is the safflower fly (*Acanthiophilus helianthi* Rossi) (11, 16, 39, 67, 109). Though this pest is widespread in the area about the Mediterranean and eastward into Central Asia, it was reported and described for the first time in India in 1929 (89). Long (67) stated that the future of safflower in France depended on the development of some insecticide or technique of control. Chevalier (personal communication) states that no effective control of this insect has been achieved, with the result that safflower acreage is gradually decreasing and promises to disappear altogether. The maggots of this insect devour the entire head. The insect normally lives on the wild members of the thistle family. It has not been reported in the United States. It is unnecessary to stress the importance of great care by those importing safflower from other countries to avoid introduction of this pest. While the plant breeder can develop varieties resistant to disease, it is immeasurably more difficult to develop resistance to an insect.

Other Pests

In contrast to sunflower, safflower in California and elsewhere has rarely been troubled from damage by birds when the crop is ripe. Pheasants have eaten the seeds if harvest was delayed (25). However, birds have often dug the seed out of the ground in the writer's breeding nursery.

Rodents have also been troublesome in the breeding nursery, and it has been necessary to construct fences against rabbits. Their damage in commercial fields has not been serious.

Broomrape (*Orobanche* spp.), a plant parasite, has attacked safflower in France (39). It is apparent from May to July as reddish stems about ten inches high with head-like labiate flowers. Dodder (*Cuscuta* spp.) has been found on safflower in California.

Processing

Published information on the processing of safflower is scarce. In California it has been processed by both solvent and expeller equipments, though most successfully by the latter. In using expeller equipments the procedures are similar to those used for cottonseed. The hulls are removed in part, but some hulls have been left with the "meats" to provide for more efficient processing. The hulls are ground and fed back to the safflower meal to adjust it to a standard protein content. The main difficulty with safflower has been the tendency for fine particles to stick to hulling equipment and screens. To minimize this difficulty, seed is moved by screw conveyors and not pneumatically. Expellers are adjusted to yield a meal with 6 to 6½ percent oil—this is lowered when the hulls are fed back into the meal.

There would not appear to be enough information on the solvent method of extraction to pass firm judgment on it. Two reports indicate that it has been used with success (92, 128), but in California trouble has been experienced with the hulls and fine particles floating instead of settling in the solvent.

The costs of setting up processing plants for safflower would not appear to be different from those for other oil crops (54, 129). In areas where safflower is grown on dry land in the absence of alternative oil crops, as in the western Great Plains or the Pacific Northwest, processing operations may be hazardous because of crop failure or sudden changes to crops that do not yield oil.

Utilization

Oil. Some safflower seed and meal has been exported from India, but it would appear that almost all of the oil is consumed locally. Though the oil was used in India primarily for cooking or illuminating, there has been increased interest there in its role as a drying oil (113, 125). It is used as an edible oil in Europe. In the United States domestic production has attracted national interest since 1949, most of the supply being used in the manufacture of alkyd resins and all-purpose drying oils (59). The quantity of oil has never been large enough to encourage large scale shifts by paint and varnish manufacturers from other vegetable oils except for use in specialty products.

There are many reviews of safflower oil (14, 17, 35, 50, 59, 83, 87, 90, 95, 128), so the remarks here will be brief. In many of its characteristics it lies between linseed oil and soybean oil (see Table V). The drying quality relative to linseed oil is higher than indicated by the iodine value because of the high percentage of linoleic acid and low percentage of saturated acids. The color of safflower oil is due to carotenoid pigments which bleach readily on heating (129). Because it has very little linolenic acid, it has excellent color retention properties and no after-yellowing.

With addition of suitable driers safflower and linseed oils were rather similar both in the speed with which they

TABLE V

CHARACTERISTICS OF SAFFLOWER, LINSEED AND SOYBEAN OILS *

Characteristic	Safflower	Linseed	Soybean
Iodine value (Wijs)	140–152	175–190	131–140
Color (Gardner)	6–10	8–11	8–11
Viscosity (G-H)	A–	A–	A–
Saponification No.	186–193	189–195	190–198
Acid value	0.3 to 3	0.7 to 4	0.8 to 3
Specific gravity 25°/25° C.	0.922–0.927	0.930–0.934	0.924–0.930
% Unsaponifiable	0.3–1.0	1.0–1.5	1.0–1.5
% Saturated acids	6.6	9.6	13.2
% Oleic acid	16.4	20.1	30.2
% Linoleic acid	76.7	19.5	51.2
% Linolenic acid	0.3	50.8	5.4

* Cagan and Crowley: Tables 2 and 3 (14).

dried and in the quality of paint film that they produced (90). Paint films from safflower oil showed a greater tendency to chalk than those made from linseed oil, but less checking and cracking (128). In certain varnishes safflower oil was found equal to linseed and dehydrated castor oils and distinctly superior to soybean oil (14).

The properties of safflower oil make it particularly adapted to the production of alkyd resins which have steadily replaced oil and hard resin varnishes in enamels. Again they are comparable to those made from linseed oil but superior in non-yellowing properties and slightly slower in drying (128). They dry faster than those made from soybean oil, and both are similar in non-yellowing and color retention properties.

Recently there has been developed a catalytically isomerized safflower oil with a 22–24 percent diene conjugation (83). This oil polymerizes and dries rapidly, and still retains the non-yellowing and color-retention properties of the original oil. It has properties in many respects similar to those of dehydrated castor oil. Conjugated safflower oil may be used in paints, varnishes and alkyd resins.

Safflower oil would appear to be less suitable for edible food products than

TABLE VI

COMPARISON OF SAFFLOWER HAY AND SEED PRODUCTS WITH OTHER FEEDS

	Safflower				Linseed meal ***	Alfalfa hay (good) ***
	Hay *	Hulls **	Undecorticated meal **	Decorticated meal **		
	%	%	%	%	%	%
Moisture	9.0	8.7	8.0	8.0	8.7	9.6
Ether extract (oil)	2.2	4.7	6.0	7.6	6.4	1.8
Crude protein	11.2	3.8	19.0	36.0	35.3	14.3
Crude fiber	28.6	53.1	33.0	17.5	8.0	29.6
Ash	7.8	1.4	4.0	7.4	5.4	8.2
N-free extract	41.2	28.3	30.0	23.5	36.2	36.5
Total digestible protein	7.9	...	15.2	32.0	30.7	10.3
Total digestible nutrients	59.8	...	50.4	66.0	78.4	50.3

* Scharrer and Schreiber (103): on the basis of 9.0% moisture.
** Goss and Otagaki (41).
*** Morrison (78).

many other oils. In tests under a variety of conditions the oil developed undesirable off flavors, and the same was true of a shortening made by hydrogenating the oil (117). The low stability of safflower oil has been attributed to the high content of glycerides of linoleic acid (94, 117). If hydrogenated to an iodine value of 73 to get a desirable stability, the consistency of the shortening was too hard (117). The main use, however, of safflower in some European countries appears to be in edible products. In fact, shipments of California seed have gone to France for this purpose. Scheibe and Yekta (109) found conflicting reports in the older literature on safflower oil for edible purposes, some stating that it was equal to or better than sunflower oil, others confirming the recent research.

Meal or Presscake. Safflower meal has been prepared in two forms: one without the hull, called "decorticated meal"; the other with the hull, termed "undecorticated", or "whole pressed seed", meal. As expected, the feed values of the two meals are greatly different. Results of digestion trials would indicate that the feed value of undecorticated meal is comparable to that of alfalfa, whereas that of the decorticated meal is similar to linseed meal (see Table VI) (41). In California most of it is marketed in the undecorticated form as a livestock feed. It has been consumed locally but sometimes has been difficult to market in competition with other protein meals that are available in large amounts.

The experience with safflower meal in rations to fatten livestock has generally supported the point of view that it is equal to other protein concentrates if comparisons are made on the basis of protein content. This was true when both the undecorticated and decorticated seed meals were compared with soybean meal in feeding trials with calves and lambs in Nebraska (7) and lambs in Wyoming (38). It was also true when compared with cottonseed meal and cull peas in feeding trials with steers in Washington (45).

Feeding trials with dairy cows indicated that undecorticated safflower meal could be substituted for linseed meal in the grain ration when liberal amounts of good alfalfa hay were fed (4, 98). Though not palatable alone to dairy cows, the undecorticated meal was readily consumed when added to palatable concentrates in amounts up to 25 percent of the total mixture (73). In Germany safflower cake in one test (46) depressed slightly both the yield of milk and its fat content, and in a second test (12) it depressed only the fat content. In the latter test the safflower cake caused no change in the characteristics of the milk fat (74). No objectionable flavors were noted in the milk, even when milking followed the feeding of safflower meal by one and one-half hours (73).

The undecorticated meal is of little interest to the poultry industry because of the high hull content. The decorticated safflower meal having a protein content of 41 percent was substituted in a practical ration for laying hens without affecting egg production, feed consumption, mortality or quality of eggs (42). On the other hand, decorticated safflower meal was an unsatisfactory substitute for soybean meal in rations for young chicks if there were more than two parts of safflower meal to one of soybean meal (63). Safflower meal was found to be deficient in the amino acids, lysine and methionine, which condition could be corrected by using fish meal and safflower meal in equal amounts.

Hulls. When safflower hulls (see Table VI for their composition) were substituted for grain hay in a fattening ration for steers—they constituted 46 percent of the total diet—the animals refused to eat until one-quarter of the hulls was replaced with grain hay (93). The aver-

age daily gain over a 103-day period was 1.19 pounds for the cattle on the hull diet, and 2.72 pounds for those fed the hay diet. It would appear that, except in small amounts, the hulls would not be desirable in a livestock ration. It has been suggested that the hulls might be used in the manufacture of furfural (129) or such products as alpha cellulose, abrasives, insulations and fillers (59).

Livestock Feed. Fresh safflower hay cut before blossoming was readily eaten by sheep in spite of the spines (103). It was similar in feed value to a good meadow hay, and not greatly different from alfalfa hay if comparisons are made on a dry weight basis (see Table VI). Spiny safflower that was frozen and dry could be grazed by cattle and sheep without apparent harm (112). Succulent safflower is very palatable to livestock (25).

Safflower has been made into a silage by adding fermenting agents (103). For sheep the feed value of the silage was superior to freshly cut safflower hay. As a feed for dairy cows the silage depressed milk yields from those obtained from a standard ration, but raised the fat content of the milk slightly (105). The silage was successfully used in hog rations (107).

After harvest in California safflower fields have sometimes been grazed by livestock. With sheep it is necessary that the stubble be left short, otherwise they have difficulty in moving through it.

Dried Flowers. The antiquity of safflower is recorded in the colors of the linen wrapping cloths of the mummies in Egypt (126). Carthamin, the coloring matter of the flowers, remained the main product of the crop until the end of the last century, when the synthetic and cheaper aniline dyes replaced it. Safflower is, however, still grown for this purpose in some areas. The composition of the dried flower is as follows (127):

Water	4.5–11.5%
Yellow color, sol. in water	20.0–30.0%
Yellow color, insol. in water, sol. in alkali	2.1– 6.1%
Red color, carthamin	0.3– 0.6%
Protein	1.7– 8.0%
Wax-like substance	0.6– 1.5%
Extract	3.6– 6.5%
Cellulose	38.4–50.4%
Ash	about 3%

The water-soluble yellow, which is dissolved in the cell sap, is removed from the dried flowers by washing with water. Then a dilute soda solution will remove the rest of the yellow coloring—it is present as small granules in the living plant. The carthamin ($C_{14}H_{16}O_7$), which is contained in the protoplasm and cell wall, is also dissolved in the soda solution. Separation of the carthamin and yellow pigment is not difficult because the carthamin is insoluble in acidified solutions, and the yellow pigment insoluble in the presence of lead acetate (126).

By suitable treatments carthamin could be made to produce a variety of red colors, the most common ranging from rose-red to cherry-red. The colors fade more readily than do aniline dyes. Its main use was to color cloth, and its use in India for this purpose has persisted in the presence of other dyes because it was traditionally used in the coloring of wedding garments (48, 97, 126). Its main uses now are to color cosmetics, food, confections, artificial flowers and liqueurs.

Dried flowers were designated by naming the country of origin (127). The terms Persian, Egyptian, Turkish, Bengal, Bombay, South American, Mexican, Spanish, Hungarian, Italian, Russian and German attest to the wide dispersal of safflower a century or more in the past. That exported from India increased to 10,157 cwt. in 1874–5, and was valued at £60,000 (126). The yield per acre has ranged from 80 to 120 pounds of dried flowers. A seed crop may be obtained in addition to the flowers.

Miscellaneous Uses. The spineless forms of safflower in their young stage are edible and have been used as a vegetable in India, and even more so in Burma (126). The tip of the main stem was sometimes cut off to stimulate branching, and this together with seedlings that were removed in thinning the crop were eaten as a vegetable (77). The dried leaves have been ground to powder and used to coagulate milk (13, 75).

Safflower has been used in experimentations to provide food for game birds in winter, since the heads would hold the seed above the snow (44, 49). In some countries the seed has been an important food of parrots (13) and poultry (124, 126).

There are many references in French literature (5, 18, 33, 111) to the successful use of safflower as a companion crop for small-seeded legumes, particularly for alfalfa. It was less competitive than small grains in early stages and provided shade for the legume seedlings during highest summer temperature. Good stands of grasses and legumes have been obtained in the Pacific Northwest with safflower as a companion crop (54).

The Future

Safflower has persisted as a crop for many centuries, and it might be argued that it will keep this status long into the future. However, it must be remembered that it was domesticated and improved as a source of color. Quite unconsciously past civilizations developed a crop that would yield both a useful oil and a livestock feed. However, the seed contained too much hull, which seriously reduced the feed value of the residue left after removal of the oil.

The last 30 years have seen the development of a few improved varieties for oil purposes. Though they have been selections from types grown primarily for flowers, they have been remarkably successful. Successful as they are, there is reason to expect that plant breeders can develop much better varieties. With less hull on the seed, the oil yield and the protein content of the residue will be higher. There would appear to be good possibilities of producing varieties better adapted to high atmospheric humidities. In other words, to an important extent the future of safflower as an oil crop is in the hands of the plant breeder, and he has only just begun.

Acknowledgments

Thanks are due the staff of the library of the University of California who obtained most of the papers in the bibliography. The author is indebted to Dr. C. E. Claassen and other members of the staff of the Pacific Vegetable Oil Corporation for many helpful comments and suggestions.

Literature Cited

1. Anonymous. Oregon's agricultural progress through research. Ore. Agr. Exp. Sta., Bull. 491. 1950.
2. ———. Can you make money with safflower? Farm Management 2(1): 25–28. 1952.
3. ———. Safflower, a rotating crop for rice land. Rice Jour. 55(9): 19–21. 1952.
4. ———. Dairy cows get safflower meal in test at Caldwell Station. Idaho Agr. Sci. 38(3): 2. 1953.
5. Alabouvette, L., and Rautou, S. [Biological and cultural information relative to oil crops in southern France]. [In French]. [French Min., Agr. Tech. Bull.] 28–29. 1948.
6. Argikar, G. P. Breeding of safflower in the Bombay State. Poona Agr. Coll. Mag. 41: 192–194. 1950.
7. Baker, M. L., Baker, G. N., Ervin, C., Harris, L. C., and Alexander, M. A. Feeding safflower meal. Nebr. Agr. Exp. Sta., Bull. 402. 1951.
8. Balakrishnan, M. S., and Krishnamurthy, C. S. Seedling blight of safflower, *Carthamus tinctorius* L. Current Sci. 16: 291–292. 1947.
9. Banerji, I. A contribution to the morphology and cytology of *Carthamus tinctorius* Linn. Proc. Nat. Inst. Sci. Ind. 6: 73–86. 1940.

10. Banna, A. Oilseeds, fats and oils and their products 1909–53. U. S. Dept. Agr., Stat. Bull. 147. 1954.
11. Blank, A. [The safflower fly]. [In French]. Le Réveil Agricole 55: 117. 1947.
12. Bünger, H. [Feeding experiments on milk cows with safflower cake]. [In German]. Tierernähr. 1: 408–420. 1930.
13. Cadiot, J. [Safflower]. [In French]. La Terre Marocaine 17: 7–9. 1947.
14. Cagan, B. J., and Crowley, J. I. Safflower oil. Pacific Vegetable Oil Corp., San Francisco, Calif. 1952.
15. Calvert, O. H., and Thomas, C. A. Some factors affecting seed transmission of safflower rust. Phytopath. 44: 609. 1954.
16. Chancrin, E. [Safflower, a very risky crop]. [In French]. Le Réveil Agricole 58: 178. 1949.
17. Carrick, L. L., and Nielsen, H. K. Safflower, a neglected protective coating vehicle. Am. Paint Jour. 22: (Aug. 8) 7–9, 18–20, 22–23, 26; (Aug. 15) 13–16, 20–21, 44–46; (Aug. 29) 12, 14, 43–48; (Sept. 5) 20–21, 24, 26, 28–29; (Sept. 12) 52–54, 56, 58. 1938.
18. Chevalier, R., and Piat, J. [Safflower trials]. [In French]. Prog. Agr. et Vit. 131: 232–238. 1949.
19. Chowdhury, S. Alternaria disease of safflower. Jour. Indian Bot. Soc. 23: 59–65. 1944.
20. Claassen, C. E. Safflower, a potential oilseed crop in the western states. Chemurgic Digest 7(3): 11–14. 1948.
21. ———. Safflower. A potential oilseed crop in the Western States. Econ. Bot. 3: 143–149. 1949.
22. ———. Natural and controlled crossing in safflower, *Carthamus tinctorius* L. Agron. Jour. 42: 381–384. 1950.
23. ———, Ekdahl, W. G., and Severson, G. M. The estimation of oil percentage in safflower seed and the association of oil percentage with hull and nitrogen percentages, seed size, and degree of spininess of the plant. Agron. Jour. 42: 478–482. 1950.
24. ——— and Hoffman, A. Safflower, a new crop for the West. What's New in Crops and Soils 1(8): 5–7. 1949.
25. ——— and ———. Safflower production in the western part of the northern Great Plains. Nebr. Agr. Exp. Sta., Circ. 87 (Revised). 1950.
26. ——— and Kiesselbach, T. A. Experiments with safflower in western Nebraska. Nebr. Agr. Exp. Sta., Bull. 376. 1945.
27. ———, Schuster, M. L., and Ray, W. W. New diseases observed in Nebraska on safflower. Plant Dis. Rep. 33: 73–75. 1949.
28. Conners, I. L. The rusts of safflower. Phytopath. 33: 789–796. 1943.
29. Cormack, M. W., and Harper, F. R. Resistance in safflower to root rot and rust in Alberta. Phytopath. 42: 5. 1952. [Abst.].
30. Darpoux, M. H. [New or little known diseases of safflower (*Carthamus tinctorius* L.)]. [In French]. Ann. Épiphyties 12: 297–315. 1946.
31. ———. [Treatment trials to control safflower rust]. [In French]. Comp. Rend. Acad. Agr. 34: 131–134. 1948.
32. Deshpande, R. B. Wild safflower (*Carthamus oxyacantha* Bieb.)—a possible oilseed crop for the desert and arid regions. Indian Jour. Genet. & Plant Breed. 12: 10–14. 1952.
33. Dufresse, M., and Bryssine, P. [Safflower]. [In French]. La Terre Marocaine 25: 393–398. 1951.
34. Dunlap, A. A. Septoria leaf spot on safflower in North Texas. Plant Dis. Rep. 25: 389. 1941.
35. Eckey, E. W. Vegetable fats and oils. 1954.
36. Erwin, D. C. Phytophthora root rot of safflower. Phytopath. 42: 32–35. 1952.
37. Faucillon, X. [The culture of safflower]. [In French]. L'Acclimatation 76: 86. 1949.
38. Faulkner, E. K., and Paules, L. Saffmeal for fattening lambs (2nd year's trials). Wyo. Agr. Exp. Sta., Mimeo. Circ. 12. 1952.
39. Favard, P. [Parasites of safflower in Toulousian Languedoc]. [In French]. Prog. Agr. et Vit. 137: 132–134. 1952.
40. Ghose, T. P. The oil seeds of Indian safflower. Indian Trade Jour. 42: 385. 1916.
41. Goss, H., and Otagaki, K. K. Safflower meal digestion tests. Calif. Agr. 8(5): 15. 1954.
42. Grau, C. R., and Zweigart, P. A. Safflower seed meal. Calif. Agr. 7(12): 8. 1953.
43. Guédon, A., and Viel, G. [The culture of safflower in the southern region]. [In French]. Comp. Rend. Acad. Agr. 29: 544–547. 1943.
44. Gysel, L. W. Value of safflower as a wild life food plant in Michigan. Mich. Agr. Exp. Sta., Quart. Bull. 36: 374–377. 1954.
45. Heinemann, W. W., Ensminger, M. E., and Ham, W. E. The feeding value of wood molasses, dehydrated alfalfa, de-

hydrated apple pomace, and undecorticated safflower meal. Wash. Agr. Exp. Sta., Bull. 543. 1953.

46. Honcamp, F., Eichler, C., Helms, W., and Reinmuth, E. [The origin, composition and digestibility of safflower cakes, and their feed value for milk cows]. [In German]. Tierernähr 1: 3–29. 1929.
47. Houston, B. R., and Knowles, P. F. Three diseases of safflower in California associated with *Verticillium*, *Botrytis* and excess boron. (In Press).
48. Howard, A., Howard, G. L. C., and Khan, A. R. Studies in Indian oil seeds. No. 1. Safflower and mustard. Indian Bot. Ser., Dept. Agr. Mem. 7: 237–255. 1915.
49. Hungerford, K. E. Safflower as a winter game bird food. Jour. Wildlife Manag. 12: 436–437. 1948.
50. Jamieson, G. S. Vegetable fats and oils. 1943.
51. Jenkins, B. C. Oil seed crops. New developments and possibilities. Agr. Inst. Rev. 8(5): 31–32, 67. 1953.
52. Joshi, S. D. The wilt disease of safflower. Indian Bot. Ser., Dept. Agr. Mem. 13: 39–46. 1924.
53. Kadam, B. S., and Patankar, V. K. Natural cross-pollination in safflower. Indian Jour. Genet. & Plant Breed. 2: 69–70. 1942.
54. Kellenbarger, S., Albrook, R. L., and Harrington, A. H. Safflower agronomic, processing, and economic data. Wash. Agr. Exp. Sta., Bull. 521. 1951.
55. Kennedy, W. K., and Unrau, J. A rapid method for determining the oil content of safflower and sunflower seeds. Agron. Jour. 41: 93–95. 1949.
56. Khan, A. R. Studies in Indian oil seeds. No. 3. *Carthamus tinctorius* Linn. The types of safflower. Indian Bot. Ser., Dept. Agr. Mem. 18: 81–87. 1929.
57. Kishore, H. Chromosome numbers of some plants. Indian Jour. Genet. & Plant Breed. 11: 217. 1951.
58. Klages, K. H. W. Safflower production. Idaho Agr. Exp. Sta., Bull. 222. 1954.
59. Kneeland, J. Safflower. Chemurgic Digest 13(2): 11–13. 1954.
60. Knowles, P. F., and Davis, L. L. Safflower, an oil crop. Univ. Calif., Agr. Ext. Serv. 1951.
61. Kostlan, A. [Agriculture in Abyssinia. I. Field and plant culture]. [In German]. Beih. Tropenpflanzer 14: 181–250. 1913.
62. Kostrinsky, J. [A date of seeding experiment with *Carthamus tinctorius*]. [In Hebrew]. Hassadeh 32: 360–363, 412–414. 1952.
63. Kratzer, F. H., and Williams, D. Safflower oil meal in rations for chicks. Poultry Sci. 30: 417–421. 1951.
64. Kulkarny, H. L. Systematics of safflower aphids (*Macrosiphum jaceae*). Poona Agr. Coll. Mag. 40: 85–88. 1950.
65. Kupsow, A. I. The geographical variability of the species *Carthamus tinctorius* L. Bull. Appl. Bot., Genet. & Plant Breed. IX. (Tech. Plants) 1: 99–181. 1932.
66. Kursell, C. V. [Breeding work on the new oil plant safflower]. [In German]. Pflanzenbau 15: 463–482. 1939.
67. Long, J. [Safflower]. [In French]. La Terre d'Oc 30: 368–373. 1948.
68. Malguti, G. Phytophthora blight of safflower. Phytopath. 40: 1154–1156. 1950.
69. Matlock, R. L. Safflower for Arizona. Prog. Agr. Ariz. 1(4): 5, 12. 1950.
70. Mauron, P. [Safflower in Berry]. [In French]. Prog. Agr. et Vit. 132: 365–369. 1949.
71. McFarlane, N. L. Record of experimental and commercial plantings of safflower in Riverside County. Univ. Calif., Agr. Ext. Serv., Mimeo. 1942.
72. McGregor, W. G., and Hay, W. D. Safflower—Canadian experiments. Sci. Agr. 32: 204–213. 1952.
73. Mead, S. W., Dunkley, W. L., and Hubbell, B. E. Palatability and milk flavor trials with safflower meal. Univ. Calif., Agr. Ext. Serv., News Rel. May 7, 1954.
74. Meetz, A., and Eichstadt, A. [The effect of safflower cake on the quality of milk and butter fat]. [In German]. Tierernähr. 1: 421–425. 1930.
75. Miege, M. [Complementary note on safflower]. [In French]. Comp. Rend. Acad. Agr. 31: 269–271. 1945.
76. Misra, A. P. Preliminary trials of some proprietary fungicides and weedicides in the field. Plant Prot. Bull. India 1: 63–65. 1952.
77. Mollison, J. A textbook of Indian agriculture. Vol. III. Field and garden crops of the Bombay Presidency. 1901.
78. Morrison, F. B. Feeds and feeding. Morrison Publ. Co., Ithaca, N. Y. 1947.
79. Morrison, K. J. Growing safflower in Washington. State Coll. Wash., Ext. Misc. Publ. 26. 1954.
80. Oswald, J. W., and Houston, B. R. The yellow-dwarf virus disease of cereal crops. Phytopath. 43: 128–136. 1953.
81. Pacific Vegetable Oil Corp. Safflower, the new Pacific Northwest oilseed crop. 1954.

82. ———. Safflower, a proven oil-seed crop for California. 1954.
83. ———. Safflower oil. 1954.
84. Palti, J., and Nizani, F. Safflower growing in Israel. World Crops 5: 266. 1953.
85. Pittman, D. W. Safflower, a possible economical oil-seed crop for Utah. Utah Agr. Exp. Sta., Farm & Home Sci. 5(4): 15. 1944.
86. Poddubnaja (Arnoldi), V. [A study of the use of embryological methods in the solution of some systematic questions]. [In German]. Beih. Bot. Zbl. 48, 2 Abt.: 141–237. 1931.
87. Prane, J. W. The use of safflower oil in paint vehicles. Am. Paint Jour. 38(26): 76, 80, 82, 84, 86, 88, 90, 92; Paint Ind. Mag. 69(3): 15–18. 1954.
88. Prasada, R., and Chothia, H. P. Studies on safflower rust in India. Phytopath. 40: 363–367. 1950.
89. Pruthi, H. S., and Bhatia, H. L. A new pest (*Acanthiophilus helianthi* Rossi, Trypetidae) of safflower in India. Indian Jour. Agr. Sci. 10: 110–118. 1940.
90. Pugsley, A. T., and Winter, G. Safflower: a potential oil crop for paint. Australia Munitions Sup. Lab. Rep. 171. 1947.
91. Putt, E. D. Sunflower seed production. Co-op Vegetable Oils, Ltd., Altona, Man., Canada. 1950.
92. Rabak, Frank. Safflower, a possible new oil-seed crop for the northern Great Plains and the Far Western States. U. S. Dept. Agr., Circ. 366. 1935.
93. Ramsaur, B. W. Safflower hull feeding trial. Univ. Calif., Agr. Ext. Serv., Sutter County, Calif. 1954.
94. Rao, M. N., and Swaminathan, M. Studies on the stability of safflower-seed oil. Mysore Cent. Food Technol. Res. Inst. B. 2: 211. 1953.
95. Remington, J. S. Safflower oil. Paint Manuf. 6: 50–52. 1936.
96. Rhoades, W. F., and DaValle, A. J. Heat polymerization of safflower oil. Jour. Amer. Oil Chem. Soc. 28: 466–468. 1951.
97. Roberts, W., and Kartar Singh, S. B. S. A text book of Punjab agriculture. Civil and Military Gazette, Ltd., Lahore. 1947.
98. Ross, R. H., Cleveland, G. W., and Fourt, D. L. Undecorticated safflower meal and protein content of grain for milk production. [Abst.]. Jour. Dairy Sci. 37: 671–672. 1954.
99. Rutherford, D. M. Safflower is harvested in Riverside County. Pac. Rural Press 136: 263. 1938.
100. Sabin, A. R. Safflower winning a place. Agr. Situation 34(1): 10–11. 1950.
101. Sabnis, T. S., and Phatak, M. G. A note on the classification of Indian safflower. Indian Jour. Agr. Sci. 5: 705–714. 1935.
102. Sag, G. [Culture of safflower in the Girondine region (preliminary note)]. [In French]. Rev. Int. Bot. Appl. Agr. Trop. 30: 216–222. 1950.
103. Scharrer, V. K., and Schreiber, R. [The digestibility of safflower (*Carthamus tinctorius*) in a fresh and ensiled condition by sheep]. [In German]. Zeits. Tierernähr. u. Futtermittelkunde 4: 42–53. 1940.
104. ——— and ———. [The effect of increased amounts of potassium with different fertilizer mixtures on the yield and quality of safflower]. [In German]. Ernähr. Pflanze 37: 49–52, 61–64. 1941.
105. ——— and ———. [The effect of safflower silage on milk yield and milk quality]. [In German]. Biedermanns Zentr. Abt. B. Tierernähr. 14: 417–423. 1942.
106. ——— and ———. [Nitrogen and phosphorus requirements of safflower (*Carthamus tinctorius*)]. [In German]. Bodenkunde u. Pflanzenernähr. 31: 253–262. 1943.
107. ——— and ———. [Safflower silage as a substitute protein feed for hogs]. [In German]. Tierernähr. u. Futtermittelkunde 6: 269–275. 1943.
108. Scheibe, V. A. [Breeding and cultural experiments with safflower (*Carthamus tinctorius* L.)]. [In German]. Pflanzenbau 15: 129–159. 1938–39.
109. ——— and Yekta, E. [Safflower, *Carthamus tinctorius* L., as an oil plant]. [In German]. Pflanzenbau 11: 49–67. 1934–35.
110. Schuster, M. L., and Christiansen, D. W. A root and root disease of safflower caused by *Puccinia carthami* Cda. Phytopath. 42: 211–212. 1952.
111. Scorraille, G. de. [Safflower and alfalfa]. [In French]. Le Blé et le Vin. 25 Février et 5 Mars, p. 3. 1950.
112. Sellschop, J. The production of safflower seed. Farming in So. Africa 26: 253–256. 1951.
113. Sharma, P. G., Budhraja, N. C., and Aggarwal, J. S. Utilization of tobacco seed and safflower seed oils in varnishes and paints—Part 1. Jour. Sci. & Ind. Res. 10B: 33–36. 1951.
114. Shinn, C. H. Culture work at the substations, 1899–1901. Calif. Agr. Exp. Sta., Bull. 147. 1903.

115. Sievers, A. F. Safflower, an oilseed crop. U. S. Dept. Agr., Bur. Plant Ind., Soils & Agr. Eng., Mimeo. Circ. DRP-51. 1950.
116. Smith, J. M. New varieties insure a place for safflower among oil crops. What's New in Crops and Soils **6**(4): 15. 1954.
117. Soltoft, P., and Dollear, F. G. Evaluation of safflower seed oil in edible fat products. Jour. Amer. Oil Chem. Soc. **28**: 335–338. 1951.
118. Thomas, C. A. Notes on diseases of some special crops in 1950. Plant Dis. Rep. **34**: 391–392. 1950.
119. ———. Seed treatment of safflower and varietal susceptibility to Alternaria blight. [Abst.]. Phytopath. **40**: 28. 1950.
120. ———. The occurrence and pathogenicity of *Phytophthora* species which cause root rot of safflower. Plant Dis. Rep. **35**: 454–455. 1951.
121. ———. Transmission of safflower rust on treated seed. Phytopath. **42**: 108–109. 1952.
122. ———. A greenhouse method of evaluating resistance in safflower to Phytophthora root rot. Phytopath. **42**: 219–221. 1952.
123. Thurmond, C. D., Hempel, A. R., and Marling, P. E. Safflower oil in alkyd resins and treated oils. Jour. Amer. Oil Chem. Soc. **28**: 354–356. 1951.
124. Van Buuren, H. L. Safflower in the Deccan. Trop. Agr. Jour. Ceylon Agr. Soc. **44**: 349–350. 1915.
125. Vidyarthi, N. L. Drying properties of Niger seed and safflower oils. Jour. Sci. & Ind. Res. **10B**: 170–171. 1951.
126. Watt, G. The commercial products of India: 276–283. 1908.
127. Wiesner, J. V. [The raw materials of the plant kingdom]. [In German]. Vol. 1, 4th Ed. 1927.
128. Winter, G. Safflower oil. Jour. Amer. Oil Chem. Soc. **27**: 82–84. 1950.
129. Woodward, R. E., and Severson, G. M. Industrial survey of safflower. Nebr. Agr. Exp. Sta., Chemurgy Rep. S-3. 1951.

Utilization Abstracts

Conifer Needle Oils. Aromatic oils, suitable for use in the perfumery industry, are present in the needles of spruce and balsam to the extent of about one percent. Economic factors as well as a lack of scientific and technological data have hindered commercial exploitation of these oils contained in the approximately 500 pounds of needles discarded with each cord of black spruce cut. The annual cut of black spruce in Ontario alone amounts to about one million cords, which yields enough foliage to furnish about five million pounds of black spruce needle oil. This is considerably more than the present market for the oil. The Department of Lands and Forests in Ontario, Canada, and the Ontario Paper Company have cooperated in investigating the possibilities inherent in this utilization. (H. B. Marshall).

Vetiver. Roots of vetiver (*Vetiveria zizanioides*), a grass native to South India and the Malay Archipelago, have from time immemorial been plaited by the Indians and Malayans into mats to be moistened with water and hung in windows so that houses become perfumed by a pleasant aroma thus draughted into them. The roots, furthermore, have been an important component of fumigants and of curry powder. The aboveground portions of this grass, which probably no longer exists in a truly wild state, is suitable for thatch when dried.

Vetiver, probably as a result of long cultivation, does not produce viable seed, and propagation of it in India, Java and Sumatra has for centuries been carried on by means of root division. Two hundred years ago the grass was imported into Reunion, and since then has been cultivated there for its essential oil, important as a perfumery raw material. More recently cultivation was extended to Madagascar and to Haiti. (A. M. Burger, *Perf. & Ess. Oil Rec. 46*(2): *40. 1955*).

Preparation of Starch from *Amaranthus cruentus* Seed

M. M. MacMASTERS, P. D. BAIRD, M. M. HOLZAPFEL, C. E. RIST

Starch and Dextrose Section, Northern Utilization Research Branch,[1] Peoria, Illinois

Starch from species of *Amaranthus*, because of its uniform small granule size, is useful for studying phagocytosis (1). Separation of starch from seeds of *A. leucosperma* and the characteristics of the starch have been previously reported (2). The species is South American and ordinarily unavailable in the United States.

Seed of *A. cruentus* (purple amaranth), a species which grows both cultivated and wild in the United States (3: 602), is available from botanical supply houses in this country. Extraction of starch from *A. cruentus* seed was undertaken at the request of Dr. Allen H. Minor, Laboratory for Experimental Cytology, Lenox Hill Hospital, New York, N. Y. Drs. Minor and Lee Burnett required particles of small uniform size for use in studies of phagocytosis, and supplied the seed from which the starch was obtained.

Preliminary microscopic examination had shown that *A. cruentus* starch is composed of essentially spherical granules, nearly all of which lie within the size range, 1 to 3 μ diameter. The granules are of the waxy or glutinous type, hence are colored red-brown, not blue, with iodine solution.

The starch prepared for Drs. Minor and Burnett proved to be well suited for use in their studies. Since others have indicated their need for a starch of this type for similar or related studies, and since there is no commercial source of such a starch, the method of laboratory preparation which has proven successful is offered here for the convenience of workers in preparing their own material.

[1] One of the Branches of the Agricultural Research Service, U. S. Department of Agriculture.

Experimental

The seeds (311 grams, air-dry) were steeped in one liter of distilled water for 24 hours at 8° C. The liquid was then drained from the seeds, and the latter were ground with excess water through a hammer mill fitted with a 0.027-inch aperture screen.

The slurry of ground seeds was passed once through No. 17 standard bolting silk, then five times through 200-mesh copper screen to remove fiber. The crude starch slurry was centrifuged in 250-ml. serum bottles in a cup centrifuge at 1800 r.p.m. for three minutes, after which the supernatant was decanted and discarded. The crude starch cake, which contained much dark-colored material, was suspended in about two liters of distilled water and passed through No. 17 standard bolting silk; this removed a small amount of slimy material which was discarded.

The impure starch slurry was allowed to settle in a large cylinder at room temperature. The impurities settled more rapidly than the starch, leaving an upper zone of suspension of relatively pure starch. This was removed and saved. More water was added to the lower layer, the suspension shaken, and the sedimentation cycle repeated until no appreciable separation occurred. The portions removed from the cylinder were combined, centrifuged in bottles, and a dark layer scraped from the top of the starch cake. The starch cake was then combined with its supernatant, which still

contained much starch, and the resulting slurry was supercentrifuged. Two portions were recovered separately from the batch bowl. One was nearly white and, on microscopic investigation, proved to be chiefly starch. The other was dark and of rubbery texture; under the microscope it appeared to contain more impurities than starch.

The white portion from the supercentrifuge was resuspended in distilled water and centrifuged in bottles. The supernatant was discarded and the starch shaken for 30 minutes in 80 percent ethanol. The resulting slurry was centrifuged in bottles, the supernatant discarded, and the cake resuspended in distilled water. This slurry was adjusted to pH 10.5 with potassium hydroxide solution, shaken for 30 minutes, held at 8° C. for about 16 hours, and centrifuged in bottles. The supernatant was discarded and a dark layer was scraped from the surface of the cake. The remainder of the cake was resuspended in excess distilled water and cleaned once by sedimentation, the supernatant being discarded. The residure was slurried in distilled water and the slurry adjusted to pH 10.5 as before, shaken 30 minutes, and centrifuged in bottles. The supernatant was discarded. The cake was resuspended in distilled water, allowed to settle and upper layer discarded, and centrifuged in bottles, five times each. The cake from the final centrifuging was slurried in distilled water, adjusted to pH 6.9 with hydrochloric acid solution, and allowed to stand at 8° C. for 64 hours,[2] then shaken and allowed to settle. The upper layer was discarded and the lower layer centrifuged in bottles. The supernatant was discarded and the cake was slurried in distilled water. Sedimentation and centrifuging were then repeated four times.

[2] This period was so long because a week end intervened; a period of a few hours would doubtless be sufficient.

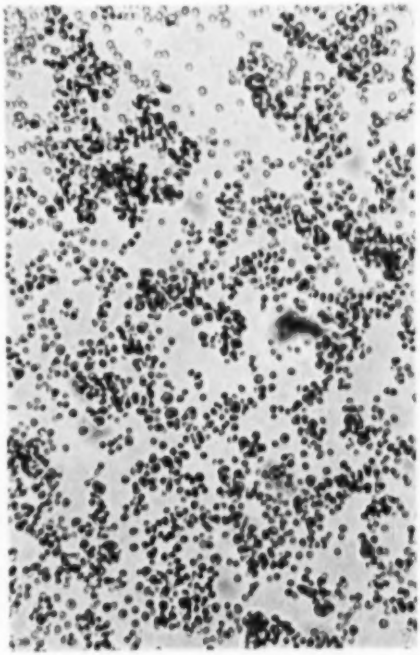

FIG. 1. Starch from seed of *Amaranthus cruentus*. × ca. 550.

At this point the starch was relatively clean, but the granules tended to clump when suspended in water. The starch was, therefore, shaken four times with 80 percent ethanol, which was removed each time by centrifuging. After the final wash in ethanol, the starch was worked with a spatula on a smooth surface until dry. The product was designated "prime-quality starch".

A combined slurry in distilled water was made of the residue from the sedimentations, the material scraped from the surface of the starch cake, and the dark material from the supercentrifuge bowl. The slurry was adjusted to pH 10.5 with potassium hydroxide solution, shaken, and centrifuged in bottles. The cake was washed five times with distilled water, from which it was removed by sedimentation in the cylinder, the super-

natant being saved and the heavier layer discarded. The slurry thus obtained was centrifuged in bottles; the starch was washed four times by slurrying with 80 percent ethanol, centrifuged after each washing, and finally worked with a spatula on a flat surface until dry. This was designated " recovered portion ".

In processing subsequent lots of seed, attempts were made to shorten procedure. These attempts were unsuccessful in that they yielded impure starch.

Results

Forty-six grams of " prime-quality starch " and 17 grams of " recovered portion " were obtained. The nitroger content (Kjeldahl), on a moisture-free basis, of the fractions was 0.02 and 0.00 percent, respectively, compared with 0.05 to 0.07 percent for commercial cornstarch.

Both fractions were readily resuspended in distilled water without clumping of the granules.

Discussion

Amaranthus starch is especially difficult to separate because of the small size of the granules. Supercentrifuging during the early stages of separation aids in removal of slimy constituents of the seed. Protein removal is facilitated by use of potassium hydroxide solution at pH 10.5 to 11.0. Higher alkali concentrations should be avoided, lest the starch be gelatinized.

There is always a considerable tendency for starch granules to clump during drying from water. The tendency is decreased as water is removed by successive alcohol washes. In the present case, drying out of 80 percent ethanol and working the starch between a spatula and a flat surface during drying were sufficient to inhibit clumping. When such technique is not wholly effective, more moisture can be removed by washing the starch several times in 95 percent, or even in absolute ethanol. Rapid drying can be facilitated by working the starch out of the ethanol on a porous plate; care must be taken, however, not to scrape fragments off the plate and into the starch.

Summary

An essentially clean preparation of *Amaranthus cruentus* starch, which could readily be resuspended in water without clumping, was obtained from the seeds. The method involved separation of other seed constituents by centrifuging, sedimentation and treatments with potassium hydroxide solution at pH 10.5 to 11.0. Tendency to clump on resuspension was lowered by drying the starch out of ethanol and working the sample on a flat surface, to break up clumps, during drying. *A. cruentus* starch is of the waxy, or glutinous, type and consists of spherical granules ranging from 1 to 3 μ in diameter. Other workers have found the starch to be useful particles for the study of phagocytosis.

Acknowledgments

The authors are indebted to Drs. Allen H. Minor and Lee Burnett, Lenox Hill Hospital, New York, N. Y., for information concerning the suitability of *A. cruentus* starch for use in studies of phagocytosis, and to M. J. Wolf of the Northern Utilization Research Branch for the photomicrograph of *A. cruentus* starch granules.

References

1. Minor, A. H., and Burnett, Lee. [Personal communication].
2. Wolf, M. J., MacMasters, M. M., and Rist, C. E. Cereal Chem. 27: 219. 1950.
3 Fernald, M. L. Gray's manual of botany. 8th ed. 1950.

Sweetest Natural Substance. An extraordinary carbohydrate, 300 times as sweet as conventional sugar, is getting an intensive going over by chemists at the National Institutes of Health. The compound is stevioside, obtained from a small shrub that grows wild in Paraguay. The crushed, dried leaves of this plant (known variously as the sweet herb of Paraguay, kaa he-e, and *Stevia rebaudiana*) have for centuries been used by the natives to sweeten their bitter maté tea. As an unusual botanical feature, stevioside is present in the dried leaves in the exceptionally high concentration of 7%.

According to NIH's Hewitt G. Fletcher, Jr., the recent interest in this natural product is purely scientific. Certainly, producers of conventional sweetening agents need not become alarmed at the prospect of any sudden, severe commercial threat. Actually, stevioside is much too expensive, is far from easy to obtain, and, in view of the ready availability of other sweetening agents, has only limited appeal. For example, the growing of the Paraguayan plant is complicated by the fact that the seeds are usually sterile, and large scale reproduction would require the use of cuttings.

Some years ago, Paraguayan growers, attempting to stir up commercial interest in this unusual crop, placed large areas under cultivation—only to have their hopes dashed when economic uses failed to materialize. Now, the plant is cultivated almost exclusively in private gardens as a botanical curiosity.

Of special scientific importance, stevioside is reportedly the sweetest natural substance known. Unlike the synthetics possessing exceptionally high sweetening power (such as saccharin and calcium cyclamate), the natural material contains carbohydrate groups, but no nitrogen. Like the synthetics mentioned, stevioside is nontoxic and, because it has little or no nutritive value, could conceivably be used by calorie-conscious weight-watchers who cannot bear the thought of eating ordinary sugar.

Several years ago, two research teams at NIH tackled the problem of determining the chemical structure of stevioside, which has the formula $C_{38}H_{60}O_{18}$. The molecule has since been found to consist of three D-glucose segments attached to a noncarbohydrate residue called an aglucon. The structure and configuration of the carbohydrate groups are now clearly defined, as are at least the general outlines of the remainder of the molecule.

The structure of stevioside is unusual in that carbon 1 of one glucose segment is hooked onto carbon 2 of the adjacent glucose segment. This relatively rare linkage is found only in the hemicellulose of Iceland moss and a few other natural products. Stevioside's third glucose segment is attached to the noncarbohydrate residue as an ester of a sterically hindered acid. This molecular arrangement is believed to be the first of its kind found in nature.

While prospects for the future commercial use of stevioside as a sweetening agent look none too promising now, the compound may find important application for quite a different reason. Like many another complex natural product, it might serve as the starting material for the synthesis of some much-needed pharmaceutical. If a medicinal use for stevioside itself can be found, here happily would be a drug with a built-in sugar coating. (*Reprinted from Ind. & Engin. Chem. 47(5)*).

Soap Plants. At least 500 genera of plants contain compounds, known as "saponins", which have the property of foaming in water and which have therefore led to some of the plants being used as substitutes for soap. Among these, utilized by the Indians of the American Southwest or by early white settlers elsewhere in America, are the following: several species of *Agave* and *Yucca* in the Southwest; the bulbous root of the California liliaceous *Chlorogalum pomeridianum*; the California pigweed (*Chenopodium californicum*); the blossoms and seed-vessels of several species of *Ceanthus*, shrubs or small trees in the western United States and northern Mexico; the berries of several species of *Sapindus* in the eastern

and western United States; the roots of the southern buckeye (*Aesculus pavia*); the gourds of *Cucurbita foetidissima* in the West; and, perhaps most widely known of all American soap plants, bouncing bet (*Saponaria officinalis*).

The only truly commercial exploitation that has been accorded to any saponaceous plant is that given to the soapbark tree (*Quillaja saponaria*) which grows on the western slopes of the Andes in Peru and Chile. The commercial material is the dried inner bark, containing 9% saponin, which is removed after the outer bark has been shaved off. It forms a copious lather in water, can be used to wash delicate fabrics and was one of the best wartime emergency materials for cleaning lenses and precision instruments. In medicine it has been used to some extent as an expectorant, emulsifying agent and cutaneous stimulant, and its ability to dissolve gases has led to its employment in fire-extinguisher solutions and to increase the foaming power of beer and of other beverages. The last use and the afore-mentioned medical utilization are to be discouraged because of its very toxic nature and a tendency to dissolve the blood corpuscles.

Brazilian Vegetable Oils. Over 30 kinds of plants are processed today for oil by 29 companies in Brazil, and oil production in that country rose from nearly 103,000 tons in 1939 to over 195,000 tons in 1950. Although most of the country produces some of the raw materials that go into this industry, five States account for 85% of the production, São Paulo alone furnishing 50%. The potentialities for further development are regarded as enormous, and in a pamphlet, "Vegetable Oils of Brazil", published by the Brazilian Government Trade Bureau (551 Fifth Ave., New York 17), brief accounts are given of 21 of these oils, five of them essential oils.

The six most important of the non-essential, or fixed, oils are those of the herb castor (*Ricinus communis*), the babassu palm (*Orbygnya oleifera*), the lofty Rosaceous oiticica tree (*Licania rigida*), cottonseed (*Gossypium herbaceum*), peanut (*Arachis hypogaea*) and cashew (*Anacardium occidentale*). Less exploited at present, only two (coconut and sesame) of the sources being cultivated, are andiroba (*Carapa guianensis*), a tree of the mahogany family; pataua palm (*Oenocarpus pataua*); coconut (*Cocos nucifera*); curua palm (*Attalea spectabilis*); the herb sesame (*Sesamum indicum*); murumuru palm (*Astrocaryum murumuru*); tonka bean, the seed of the tree *Dipteryx odorata*; tucum palm (*Astrocaryum vulgare*); ucuuca trees (*Virola surinamensis* and *V. sebifera*); and uricuri palm (*Attalea excelsa*), known also as "licuri" and "ouricuri".

The five essential oils considered in this pamphlet are those of copaifera (*Copaifera* sp.), rosewood (*Aniba rosaedora* var. *amazonica*), mint (*Mentha arvensis*), sassafras (*Ocotea pretiosa*) and orange (*Citrus sinensis*).

Brazil furnishes most of the castor oil used in the United States, where it enters an ever increasing variety of industrial outlets, the least of which is as a medicine. The oil from babassu nuts is one of the potentially great, but so far only partially exploited, plant products of Brazil. Between two and three billions of trees of this palm are estimated to grow wild in the country, and the oil obtainable from them is used in the manufacture of high-grade soaps, shaving creams, perfume and margarine. About 175,000 people gather and crack the oil-yielding nuts, the extreme hardness of which has presented a considerable problem in developing efficient mechanical crackers, and this in turn has delayed full exploitation of the crop. Oiticica oil, from the seed of oiticica trees, is a valuable drying oil for varnishes and enamels, and those from cottonseed, peanut and cashew have their particular uses.

Bahamian Medicine. Inagua, the southernmost of the Bahama Islands, 560 square miles, 400 miles southeast of Nassau and 65 miles north of Haiti, was without modern medical service until very recent years, and the 1,000 inhabitants have long depended upon native plants in finding remedies for their ailments. Forty such plants are listed in this article, giving common and scientific names, preparation and dosage, and comments from the U. S. Dispensatory and Webster's New International Dictionary. (W. H. Sawyer, *Sci. Mon. 80(6): 371. 1955*).